



The Blast Furnace and Steel Plant

Published the first of each month by the National Iron and Steel Publishing Co.

Main Office — Thaw Building, 108 Smithfield Street, Pittsburgh.

DISTRICT OFFICES — NEW YORK AND CHICAGO.

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Subscription Price:—In the United States, \$1 per year; Canada, \$1.50; all other countries, \$2. Single Copy, 15 Cents.
Entered as second-class mail matter at Pittsburgh, Pa., under the Act of Congress, March 3, 1879.

Table of Contents

VOL. VIII.

APRIL, 1920.

No. 4

	Page		Page
THE CARE OF ROLLS IN SHEET AND TIN MILLS	223	ECONOMY OF STOKERS AND TURBO GENERATORS	252
BY W. H. MELANEY.		AUTOMATIC GRADUATED POWER PLANT CONTROL	256
NEW EQUIPMENT INSTALLED IN FRENCH WORKS	227	BY F. A. MORELAND.	
FORGEABILITY OF IRON-NICKEL ALLOYS	231	LOSSES FROM LONG SUPERHEAT STEAM PIPES DETERMINED BY MEANS OF CURVES	250
BY T. D. YENSEN.		BY THOMAS G. ESTEP.	
HEATING FURNACES AND ANNEALING FURNACES—PART XVI	234	FOREIGN RELATIONS	262
BY W. TRINKS.		PRODUCTION TOPICS	263
PHYSICAL CHANGES IN IRON AND STEEL BELOW THE THERMAL CRITICAL RANGE	238	NEWS OF THE PLANTS	264
BY ZAY JEFFRIES.		OPEN HEARTH	265
ELECTRIC ROLLING MILL DRIVE EQUIPMENT	245	INDUSTRIAL RELATIONS	267
BY J. D. WRIGHT.		SOME POINTERS ON BY-PRODUCT COKE OVEN OPERATION	268
PRESENT STATUS OF NICKEL-CHROMIUM ALLOYS	249	WITH THE EQUIPMENT MANUFACTURERS	269
BY W. A. GATWARD.		TRADE NOTES, TRADE PUBLICATIONS..	270

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VOL. VIII.

PITTSBURGH, PA., APRIL, 1920.

No. 4.

The Care of Rolls in Sheet and Tin Mills

An Analysis of the Causes of Roll Troubles and Practical Methods for Preventing Breakdowns—Proper Methods for Taking Care of Rolls—Present Day Rolls Are Superior to Those of the Past.

By W. H. MELANEY.

THIS is a subject on which there is a greater divergence of opinion than on most subjects pertaining to rolling mill work. The reason is that because of the massiveness of such rolls, most of which are from 28 to 30 inches in diameter and weighing anywhere from five to seven tons apiece, few of the men directly connected with their use seem to realize the extreme sensitiveness to heat variations of these apparently unbreakable chunks of metal.

As it is imperative that sheets with a smooth finished surface be produced to meet the requirements of the trade, it became necessary for the roll maker to develop a roll with an extremely hard face in order that the roll might stand up under these conditions for a length of time that would meet the practical conditions in a rolling mill.

This means that as a 24-hour day is divided into three turns of eight hours each and the work is continuous, and as the roll trains are not operated on Sunday, it is desirable that the rolls stay continuously on the job for a week at a time without having their surface refinished in any way except by scouring up with a carborundum block, which is done by the crew, as often through the turn as the surface shows signs of roughing up.

But at the end of each week the pair of rolls are removed from their housings and go back to the roll turner to be placed in the roll lathe and machined on the rolling face to a perfect surface again, taking out the extreme hollow in the

face of the rolls that results from wear, and the scouring that is necessary to keep them smooth throughout the week.

After many years of use and experiment it has been proven that the most satisfactory roll to meet all conditions and give the necessary finish to the surface of the sheet, is what is known to the trade as a chilled roll and at the present time this is the only type of roll used to finish sheets, although gray iron, semi steel, steel, or alloy rolls are used in the roughing stands where a separate roughing stand is provided, this being principally confined to sheet mills, as the roughing and finishing is usually done on one stand of chilled rolls in a tin mill.

Chilled rolls, as the name implies are provided with a chilled, hardened face on the surface where the sheet actually comes in contact with it during the process of rolling. The balance of the roll being of grey iron and no harder than the ordinary grey iron casting.

The method of producing this hard or chilled face on an otherwise

comparatively soft casting seems to be pretty much of a mystery to even the men who have rolled on them for years, although the roll maker and foundrymen have been familiar with this process for a great many years.

Due to the accepted theory that cast iron in its molten state has all of its carbon in the combined form and as is proven by analysis that the chilled face of the roll has practically all of its carbon in the combined form, it would seem natural to imply, that if the molten cast iron could be cooled or frozen to its solid state so quickly

This is the first of a series of very interesting and practical articles on the subject of sheet mills. Mr. Melaney has had extensive experience with sheet mill problems and his articles will be of great interest to sheet and tin mill men. In this article Mr. Melaney tells about the characteristics of sheet and tin mill rolls, the proper way to warm up, how to regulate the output and how to enter the pack during the warming. What is the proper way to avoid rough surfaces on rolls? What factors cause a rough surface? Are you sure you know why rolls spawl? Are your rolls properly turned? These and many other questions are answered in this article.

that the combined carbon could not separate out in the form of graphitic carbon (which most of it would do if cooled slowly) that the surface so produced would, due to its combined carbon, be very hard. This on experiment proved to be true. Therefore, to produce a chilled face it is necessary to freeze the molten iron rapidly.

Of course it is not the writer's intention to imply that any cast iron mixture, rapidly cooled, will produce a hard face, even though chilled. There are chemical constituents when present in certain proportions, such as silicon and manganese that would prevent the carbon remaining in the combined form on cooling, therefore, it is essential that for a given depth and condition of the chilled service it is necessary to have the right chemical mixture to start with.

This having been accomplished, a mould is constructed in which the rolling surface of the roll is formed in a very heavy iron cylinder which freezes the molten iron suddenly and before the carbon can separate out in the form of graphitic carbon, thus producing a chilled surface, while the necks and wabblers are cast in sand or loam which permits of a very slow freezing of the molten iron and a consequent separation out of the graphite, thus producing an unchilled iron.

This then produces a composite casting with the rolling surface chilled hard and all the rest of the casting of a texture and hardness similar to ordinary cast iron, and herein is where the trouble all starts.

As it is apparent that a roll has now been made, the various parts of which have radically different characteristics, but which must of necessity receive the same treatment.

The chilled surface being of a highly crystalline structure similar to glass or ice and about as sensitive and with a much higher ratio of expansion and contraction than the unchilled portions must, due to the very nature of the sheet rolling process, be the first to become heated up. This surface gets most of its expansion before the grey body of the roll becomes even warmed through. This produces a condition that tends to tear the chilled surface away from its slower expanding center, the extent of this action depending on the rapidity with which the surface is heated, and it is therefore a logical conclusion to assume that the

slower the heating takes place the less violent the action and therefore the less danger of a rupture of the roll.

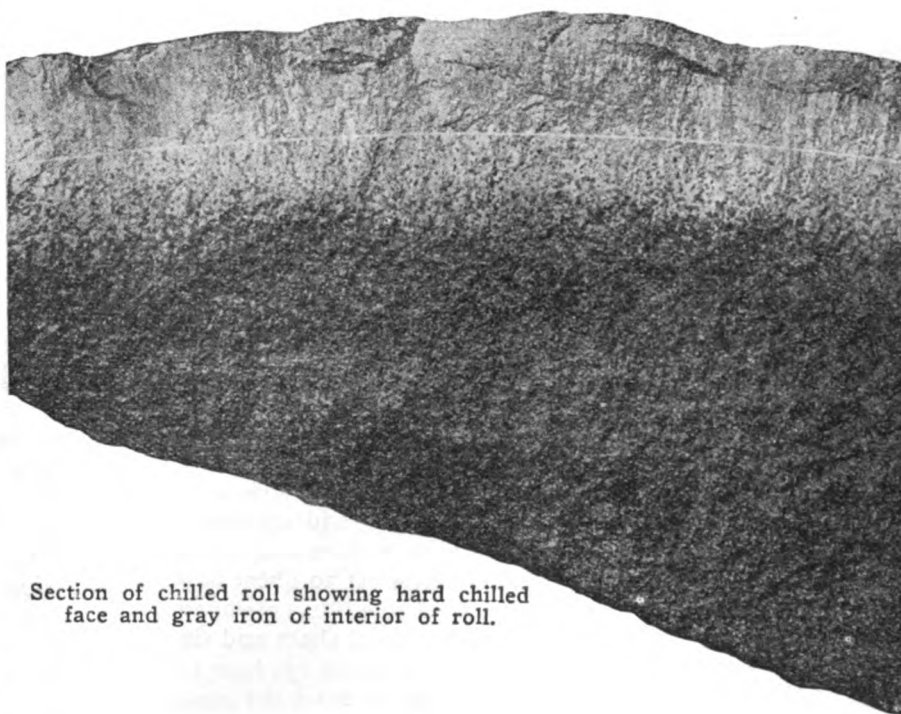
It is of course necessary in sheet and tin rolling, to warm up the rolls before attempting to finish any sheets. There are two primary reasons for this. First, because the rolls are turned so that when placed on top of each other in a cold condition they only touch at each end of the rolling surface. This is what is termed the cross in the rolls, and is so called because in fitting the top and bottom rolls, while turning in the roll lathe the one roll is not placed parallel to the other, but is set across to an amount corresponding to the practice of that particular mill and then the surface of the other roll, hollowed out until the surface of the two rolls fit perfectly. This puts a certain amount of concavity into the roll to allow for future expansion, due to its being hotter in the center

than the ends of roll. The other primary reason is that if the rolls were not warmed up slowly the rapid expansion of the face of the roll over the metal in the interior of the roll would cause excessive roll breakage which, of course, would be expensive. Therefore, most mill managers insist on the crews following some such system as that described in the following paragraphs.

The first three "turns" should be limited to not more than 80 per

cent of the normal output and on the first three "charges" the bars should receive double rolling, that is, rolled in singles then matched in pairs, reheated and rolled, then matched in threes and doubled, reheated and finished, this refers to narrow iron of 22 to 24 gauge, which should be used for warming up and after the middle of the week when the rolls are in an ideal condition the crews are permitted to increase their tonnage sufficient to make up the tonnage lost on warming up turns, as when the rolls have acquired a temperature of 700 to 750 degrees, there is little danger of breaking even with the slight increase of tonnage, so long as the temperature is kept fairly constant.

One thing that must not be lost sight of is that it is not necessary to heat a roll to a high heat before there is danger of breaking it. A roll may break from heat expansion before it is hot enough to discolor, in



Section of chilled roll showing hard chilled face and gray iron of interior of roll.

fact when it is still cool enough to touch with the bare hand, providing the heat is too quickly or unevenly applied and even after the roll has been properly heated, rapid changes in its heat, either up or down will break it.

Rhythmic Regularity of Entering Pack.

Another condition that is entirely overlooked on sheet and tin mills that may cause considerable roll breakage and which is especially dangerous on the warming up turns is the rhythmic regularity with which the singles and short packs are sometimes entered into the rolls.

The roller and catcher become so mechanically proficient that the time between passes becomes practically constant and the sheet or pack being short only requires part of a revolution of the roll to deliver it, with the result that the sheet enters the roll for a number of passes in succession at approximately the same spot on its circumference.

This means unevenly heated rolls, inasmuch as they get much hotter on that side than on the opposite side. This is the worst condition that can possibly obtain so far as roll breakage is concerned and is probably responsible for many rolls breaking before they are hot enough to discolor.

Concaving Rolls.

There is considerable difference of opinion among the rollers and mill managers, both as to the amount of the cross and whether the concavity should be all in one roll, the other roll remaining straight, or whether it should be equally divided in both rolls.

From years of practical experience as a roll turner I doubt if there is really any practical advantage of one method over the other, although theoretically the advocates of placing the cross in both rolls have some argument to support their claim which is as follows: When only one roll is concaved, the amount of concavity must be double what would be placed in either one of the rolls were both to be concaved, therefore, the difference in diameter between the middle and the ends of a single concaved roll is greater when the rolls are cold than would be true when both rolls are concaved. Therefore, when the rolls are thoroughly warmed up until they fit in the case of the concavity, all being in one roll, this roll would still be a little concave, while the other roll would be slightly convex. This, of course, is not apparent to the eye nor on the pack but it does remain true that, due to this condition the center on one roll is slightly smaller, and the center of the other roll slightly larger in diameter than the ends of the roll, and it is contended there is an appreciable slip between the two parts of the roll's surface which tends to produce a roughness on the surface of the sheet, but it seems to me this is drawing the lines a little fine and is almost impossible to prove in practice.

There are many other causes, which would produce roughness, several of which may exist at the same time. Much more slippage of the top roll can take place through a poorly lubricated top neck, than could possibly occur from this light difference in diameter and would thereby produce either a rough surface or gathering.

Rough Surface on Rolls.

This may be due to several causes all independent of each other. There may appear, due to poor turning (but mostly to excessive wear from forcing greater output on the mill) high spots or ridges on the roll's face which means that this part of the roll surface is subjected to greater pressure or crushing strain than the rest of the surface, inasmuch as the surface, as stated, is a crystalline structure like glass or ice, this crushing pressure has identically the same action on the chilled surface as would be the case were it glass or ice, except of course in a lesser degree and therefore it is less apparent to the eye, but the direct result is a breaking up of the fine crystals on the surface of the roll. If the crushing strain is long continued, and of sufficient force it will produce striations down into the chill at right angles to the face of roll, the same as would occur in glass or ice if crushed and if this crush be continued it may develop into a spawl.

Gathering.

The roughness may be due to gathering on the face of the roll, which is caused by small particles of steel being torn out of the surface of the pack and practically welded under the extreme pressure to the face of the roll. This gathering is very hard to remove, the scouring block having little effect on it, after it has once been permitted to develop to any extent, but it can be prevented if the scouring is sufficiently vigorous before it develops. This condition is oftentimes due to poor lubrication of necks, causing a slippage between the rolls which tears small particles from the pack, or to excessive screw.

It is also aggravated by using steel of very low phosphorous content. However, it is not a defect of the roll as formerly claimed, although an extremely soft face might aggravate it somewhat.

These small particles of steel gather on the face of the roll and are welded on to each other until they stand up on the face of the roll in ridges and are elongated into streaks, which sink into the face of the sheets, cutting grooves that can not be eliminated by cold rolling and in the case of very thin sheets, cut slits through the outside sheets. A proper use of the scouring block will prevent this condition, but when once allowed to form they must be cut from the face of the roll with a turning tool to thoroughly remove them.

Spawling.

There are only two known causes for spawling, one is an inherent defect in the roll, due to a cold shut in pouring, and when this happens it cannot be hidden but shows on the face of the roll, when the surface is first turned. If no cold shut appears on first turning (and a cold shut is a rare occurrence and would be a cause for scrapping the roll at the foundry) it is a positive guarantee that any future spawl is not due to this cause, this is why roll manufacturers refuse to replace a spawled roll.

The other cause for spawls is a crush which may be caused in many different ways. A pair of tongs may be rolled, a bar gagged in the mill, a corner of the pack may become cold and crush the surface of the roll, excessive screw on a cold pack, a high bearing on face of roll, or a small piece of the pack be bent

over and go through double. Using rolls too hollow will also cause spawls.

If any of these causes obtain the chilled surface at that particular point becomes crushed and striations extend down through the chill, the same as would happen if you struck a crushing blow on a plate of glass, and while the roll may not spawl then, those striations always exist and some time may let go and the result is a spawl, the cause for which may have happened weeks before, and been forgotten, this is why many mill managers will conscientiously say that nothing happened to cause the roll to spawl.

Breaking of Rolls in Service.

The causes for roll breakage are legion and no matter how careful a mill manager may be or how good his mill practice, he will always have more or less of this trouble, though of course, the more he keeps in touch with the actual conditions in his mill and the better judgment he uses, the less will be his roll breakage.

One point of all others that should not be overlooked, is that most of the roll breakage, no matter when it finally occurs was primarily started on the warming up turn, this is why many rolls actually let go when there is nothing in the mill, of course some rolls that have given a long life actually break in the end, due to fatigue of the metal comprising them and when this is the case, will break when no undue condition happened to indicate it.

Therefore, it is the warming up turn that requires the most attention.

Did it ever occur to you Mr. Manager that chilled rolls are as sensitive as a piece of glass so far as expansion and contraction is concerned? And like glass will stand for a lot of heat without serious results after you have once gotten them warmed through to the center, but if you attempt to warm them too rapidly the same thing happens as happens to glass under this condition, they go to pieces.

Therefore it is advisable, especially in the winter time, to use some means of preheating the rolls through to their very center, to a temperature as hot as you could bear your hand on before attempting to warm them up by rolling bars on them.

This can best be done by revolving the rolls early Sunday evening and while they are in motion, spread over their surface by means of a perforated pipe connected with a hot water heater, enough boiling water to heat them through to the center, this is the ideal method as the water spreads over the entire surface of the rolls and heats them evenly all over, this is continued until ready to start the mill on its first turn, when a limit should be placed on the first three turns.

After the rolls have been fully expanded and have reached a temperature of 700 to 750 degrees F., they are in condition to produce full tonnage without undue risk.

But there is one other feature that is generally overlooked in a sheet mill, that is preventing the too rapid cooling of the rolls after the week's work is finished and this is almost as bad as too rapid heating.

When the rolls are removed from their housings on Saturday they should be placed with their necks

resting on wooden supports that are high enough to keep the surface of the roll out of contact with anything, then a closed cover placed over them fitting closely along the bottom so as to prevent the rapid radiation of heat and the consequent rapid cooling of the roll and left in this condition until Monday, especially is this true in winter, as if left unprotected they cool unevenly and perhaps break the next time they are used.

Too much care can not be taken in seeing that the rolls, after a temporary shut-down of the mill, are permitted to run idle for a few minutes in order to even up the temperature of the various parts of the roll which become uneven when they have been left to stand. If the shut-down is of a few minutes duration, a few well heated crop ends should be rolled before resuming the general work on the mill.

Also where steam or air is used to cool the rolls it must be shut off immediately the mill is stopped, otherwise you will have uneven cooling of the rolls and subsequent breakage.

Most rollers prefer to use the hollow roll on the top as the top roll gets much the hottest, principally due to the hot pack being continually shoved back over the surface of the top roll in rolling, and is also augmented by the heat arising from the bottom roll.

Proper lubrication is also a great factor in preventing hot necks or gaging of rolls which all tend to produce excessive roll breakage, as once a roll is gagged, conditions are set up that mean, sooner or later, these rolls will break.

Many rolls are broken by either turning them too hollow or using them on wider iron than should be rolled on them in the condition that then exists, this means that the rolls must be forced up in the center and the ends of the rolls kept too cool for safety, in order to get gauge on wide sheets often resulting in a difference of temperature of over 200 degrees between the ends and center of the roll face, this is a dangerous practice.

Many men in a mill believe that by cooling the ends of the rolls they force the heat into the center of roll, this of course is not true, it simply permits the center to get hotter from the hot packs being rolled, while the ends are kept cool by dropping water on the necks or wabblers and of the two methods putting the water on the wabbler is preferable, as the water running over the necks carry grit into the brasses on which the necks run and wear them away unnecessarily, especially if it contains any sand or silt.

Where water is run on the neck it should be done by using a perforated pipe with a closed end so that the water is not projected onto the fillet, as this is very apt to cause a crack in the fillet due to the great difference in temperature between it and the roll body and later on a broken neck or spawled end of roll.

Turning Rolls.

The roll turning is a very important item and should be in charge of a man not only skilled in the art mechanically, but one having good judgment, as much depends on this.

The next installment of this series will take up roll turning in detail.

New Equipment Installed in French Works

Description of 700 Ton Hot Metal Mixer and 60 Ton Ladle Cranes Recently Installed at Works of the Normande Steel Works, France.

THE following description of the metal mixer, ladle cranes, soaking pits, billet handling cranes, etc., recently installed at the steel works of the Societe Normande De Metallurgie, Caen, France, as well as the illustrations, appeared in a recent issue of "Engineering," London, England. The description is deemed of considerable interest to American engineers and is therefore reproduced in the following article:

Figs. 3 to 5 show a 700-ton metal mixer which is employed to store the hot metal coming from the blast furnace and pass it on as required, to the converter plant. This mixer is of the circular type, designed to hold a depth of metal 11 feet 2 inches. It is 27 feet long inside and 15 feet 10 inches in internal diameter. It is fired by blast furnace gas, air pre-heated in a regenerator chamber being employed to promote combustion. The heat is required to balance

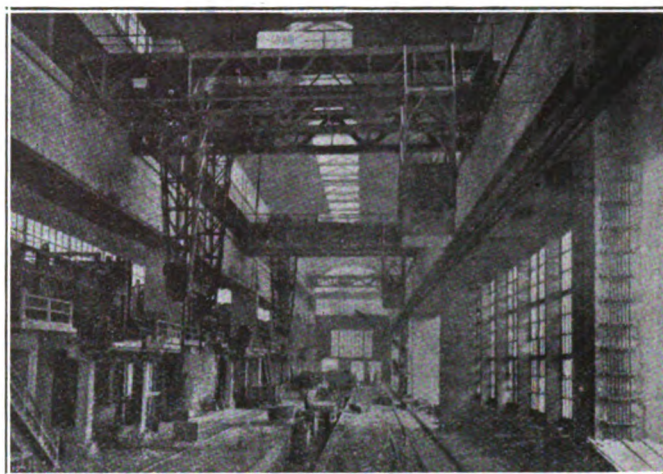


Fig. 1—View of 60-ton ladle cranes over the casting pits.

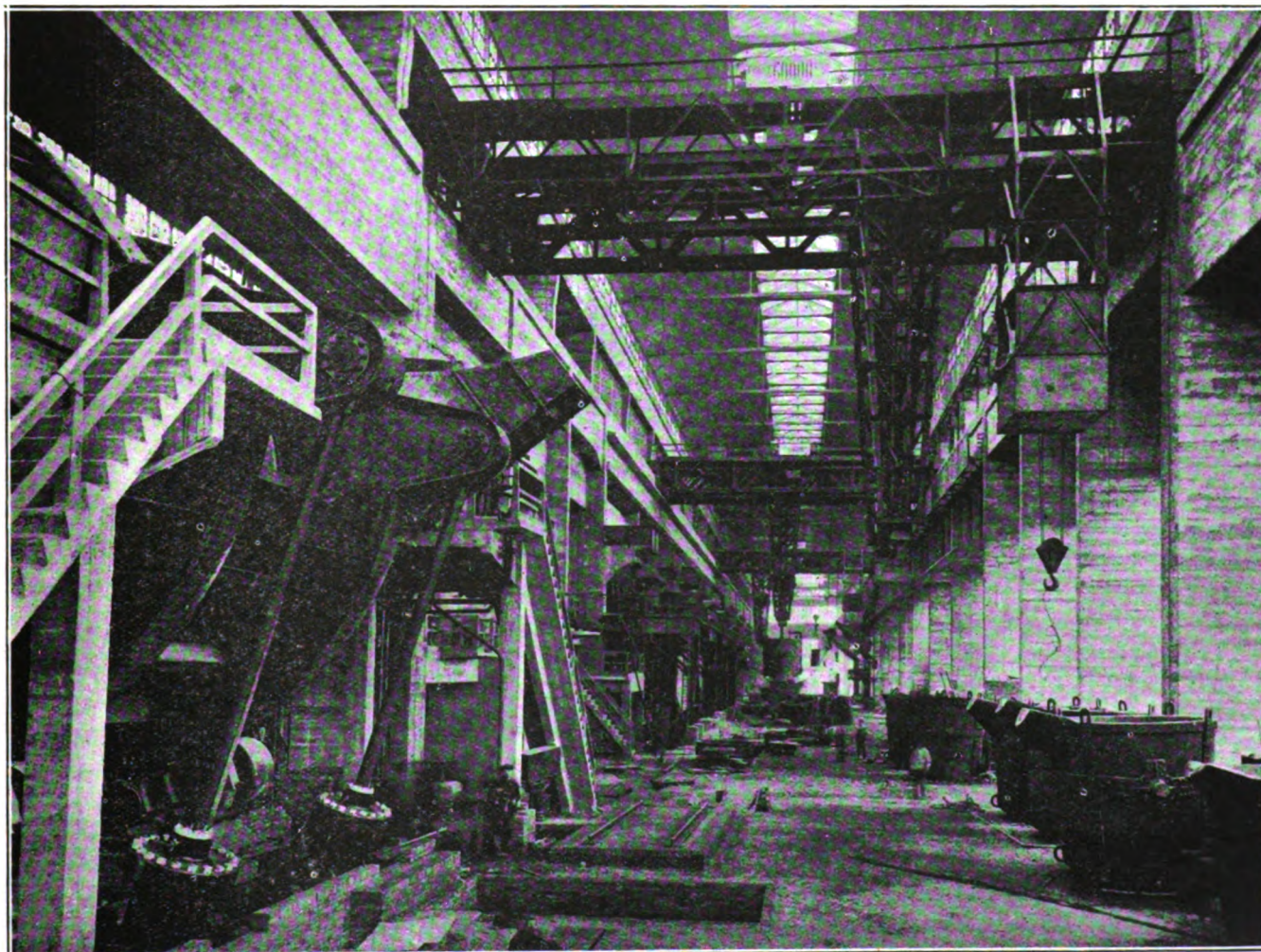
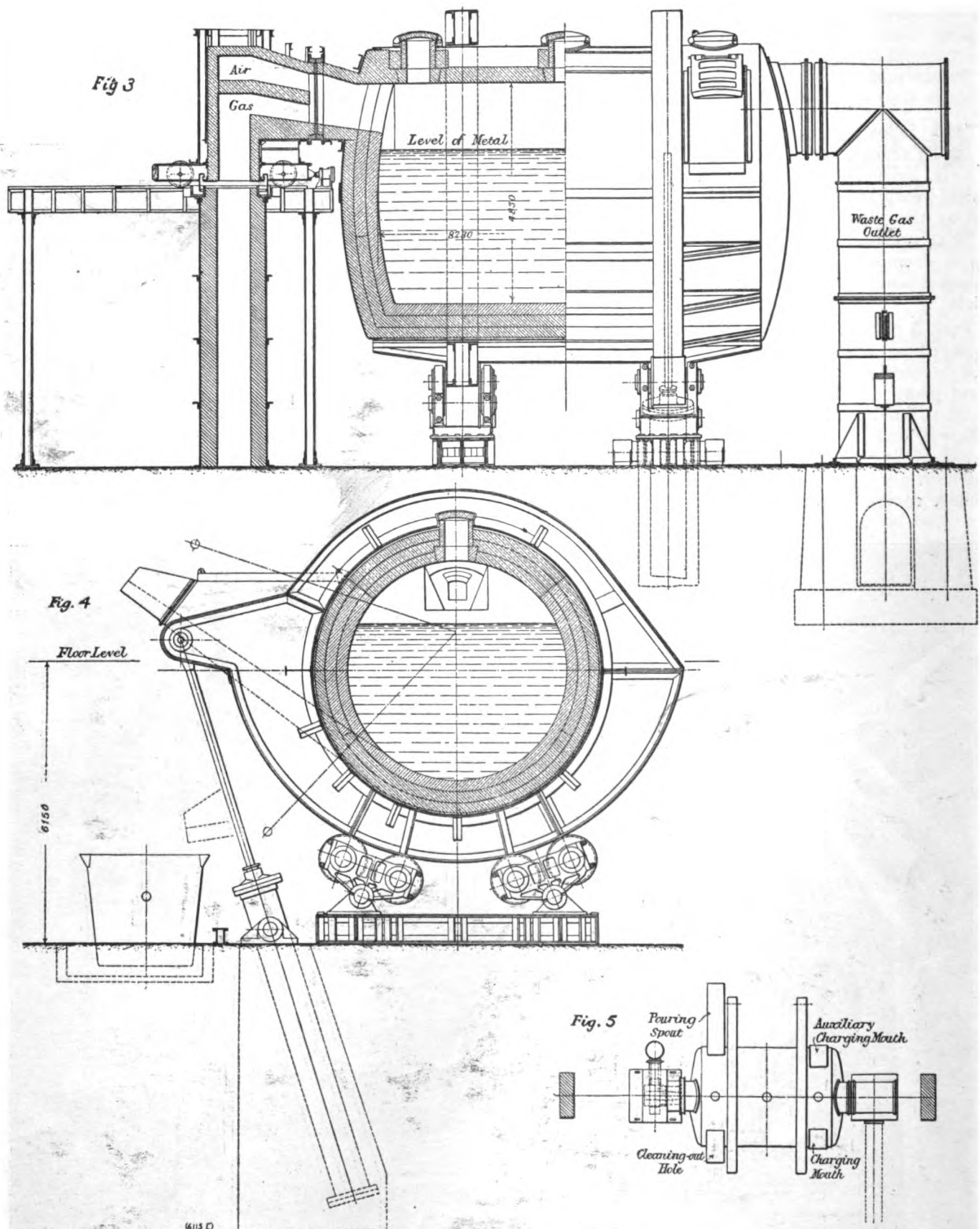


Fig. 2—General view showing the metal cranes and metal mixer.



Figs 3-5—700-ton metal mixer at the works of the Societe Normande de Metallurgie, Caen, France.

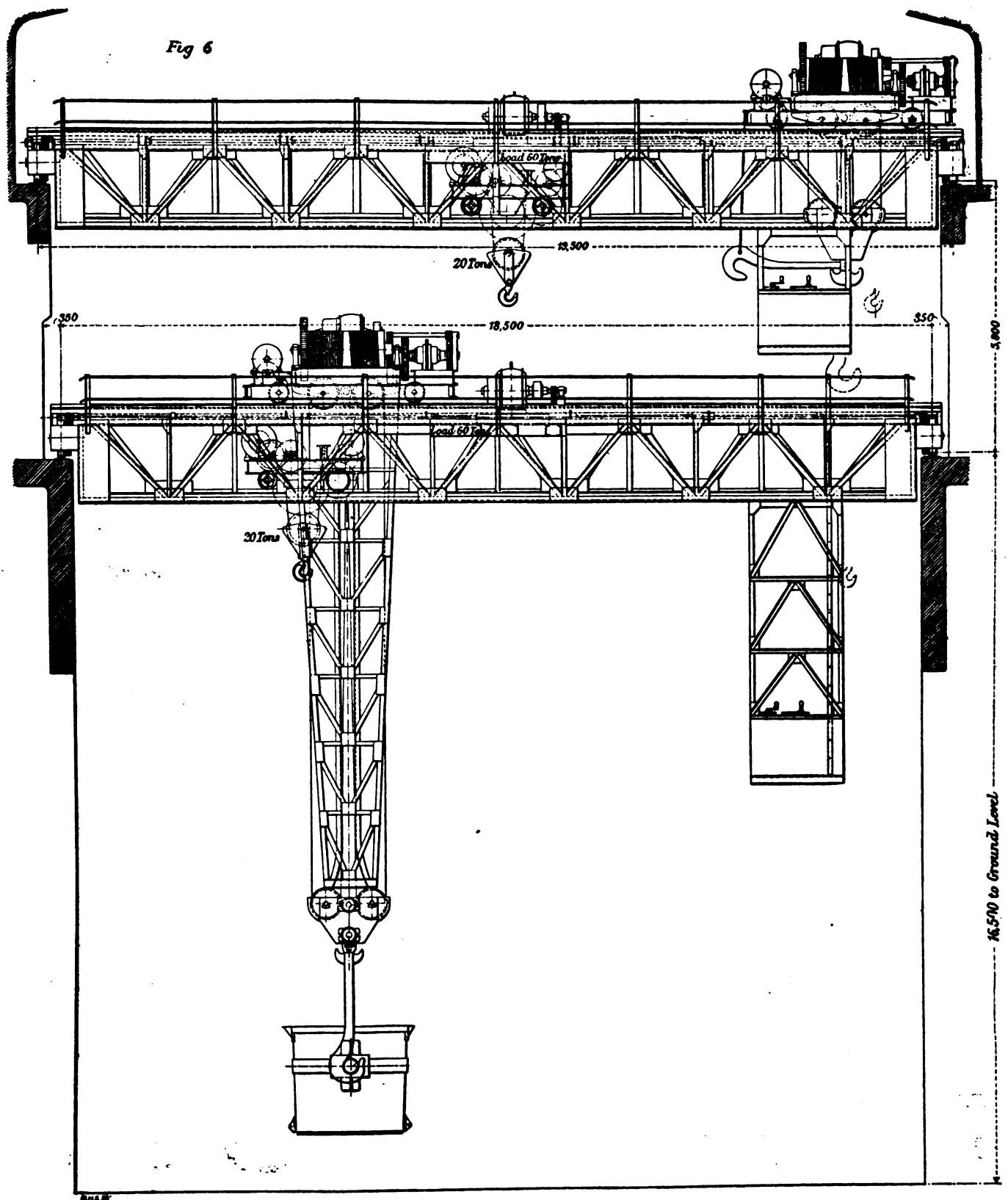


Fig. 6—Sixty-ton ladle crane constructed by the Wellman, Smith, Cwen Engineering Corporation, Ltd., Engineers, London.

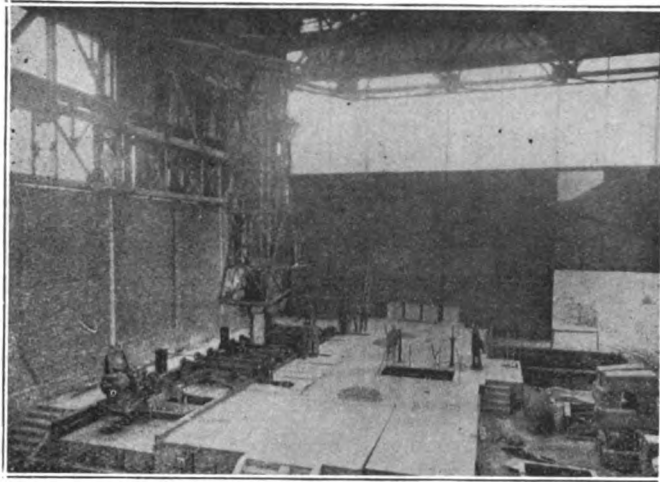


Fig. 7—View of soaking pits and combined stripping and charging cranes.

radiation losses, and keep the metal in a suitably molten state for transference to the open hearth furnaces. The mixer is made of shell plates, $1\frac{1}{4}$ inches thick, double butt strapped at the joints and stiffened throughout with girder section stiffeners. It is mounted on eight articulated rollers so that the load is evenly distributed. The mixer is tilted by means of two double-acting hydraulic cylinders working in

pits. The cylinders are designed for a pressure of 700 pounds per square inch. The mounting and tilting gear will be seen in Fig. 4 and Fig. 5, which gives a plan of the mixer to a smaller scale. Fig. 5 shows at the right hand end of the body two rectangular openings. One of these is the main charging spout, and exactly opposite is an auxiliary charging spout. Towards the left-hand end of the mixer are two other spouts. The smaller, on the near side, is a slagging spout. The long spout opposite is the main pouring spout, also well shown in Figs. 4 and 5. This again will be noticed in Fig. 2, which shows the mixer in relation to the rest of the plant. Incidentally, some idea of the size of the mixer may be gathered from the figure of a man shown in this view standing below the stairway leading to the upper platform. All these spouts are fitted with covers to retain the heat, as shown in Fig. 4. The top of the vertical gas uptake is mounted on wheels, forming a movable port end, and may be moved away from the mixer inlet. The arrangement of the seal is shown in Fig. 3. The vertical gas uptake may be seen in Fig. 2, on the further side of the mixer.

The 60-ton ladle cranes are shown in Fig. 6, each equipped with one 20-ton auxiliary trolley. There are five of these cranes installed. Four are of the type shown in the lower part of Fig. 6 and again in Figs. 1

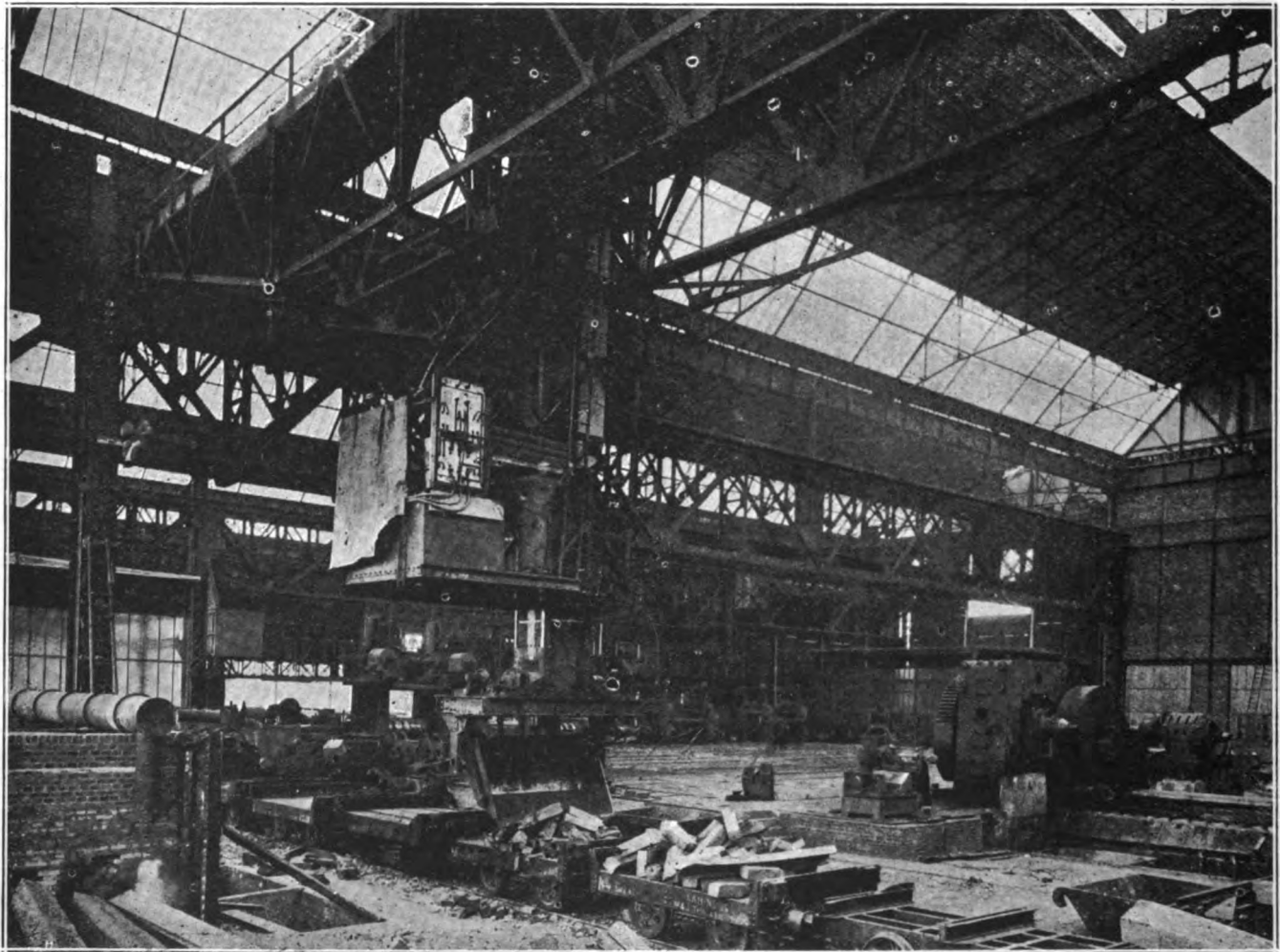


Fig. 8—Billet handling crane.

and 2, these being employed for casting, while one of the type shown in the upper portion of Fig. 6 is used to carry the hot metal from the mixer to the Thomas converters. The lower crane is fitted with guides to the lifting gear, in the form of a long hanging frame fixed to the crab. This, of course, serves to steady the ladle, as will be seen in the drawing. These cranes have a longitudinal speed of 246 feet per minute, obtained from an 80 hp motor. The main crab has a cross-traversing speed of 98 feet per minute. This is given by a 20 hp motor. The hoisting motor is 80 hp, giving a hoisting speed of 13 feet per minute. The design of the crab or trolley is open, and all shafts are easily accessible and can be removed without dismantling other gears. The load is taken on 16 ropes winding on two barrels. There are four separate ropes. The standing ends of two on each side are attached to compensating beams which have a movement of one inch. In the event of a rope breaking, the load can only fall one-half inch, and would be carried by two ropes diagonally across the trolley. The auxiliary trolley, of 20 tons capacity, has a 50 hp hoisting motor, giving a hoisting speed of 24 feet per minute, and a traversing motor of 10 hp giving a speed of $14\frac{1}{2}$ feet per minute. Solenoid brakes on the motor, and Weston load brakes, are provided on the main hoist, and potentiometer resistance control for the lowering of the auxiliary hoist.

Fig. 1 shows the casting pits. Metal is poured into the moulds with the latter either in the pits or standing on small platform trucks on the track, as may be seen in the distance of this view. Thence the ingots are taken off to the stripping crane, which is illustrated in Fig. 7 working over the soaking pits. This combined stripping and charging crane is there seen

placing an ingot, stripped of its mould, in the soaking pit. Two of these pits are employed. They are of the producer gas-fired regenerative open-cell type. The pit cells are 40 feet 4 inches long and 7 feet $6\frac{1}{2}$ inches deep, while the width tapers from 6 feet $10\frac{1}{2}$ inches at the top to 6 feet 11 inches at the bottom. Each pit will hold 16 ingots of a maximum size of five tons each. The pits are controlled by 24-inch Forter gas reversing valves and 33-inch butterfly valves. It will be seen that the pit covers are of the rolling pattern, being divided into five sections for each pit, each section being carried by four small wheels. They are moved by a rack-and-pinion drive geared to a 30 hp electric motor.

Another of the interesting cranes at these works is shown in Fig. 8. There are two of these at the Caen works. They are intended for handling hot billets, carrying them from the blooming mill to the finishing mill reheating furnaces. The cranes operate in parallel bays, and each has a span of 94 feet 9 inches. They have a longitudinal travel of a speed of 492 feet per minute obtained from an 80 hp motor. The cross traverse is by a 20 hp motor, giving a speed of 286 feet per minute. The hoisting speed is 39 feet per minute, obtained with an 80 hp motor; while for slewing, a 10 hp motor is provided, giving a speed of 3 rpm. The hooks are raised at a speed of 20 feet per minute by means of a 10 hp motor.

From a study of the illustrations it will be noted that the vertical revolving mast is guided over practically its entire length. The billets are usually carried in pans which are tilted for discharging, as shown in Fig. 8. Arrangements are made for electromagnets to be attached to the beam, instead of the pans, so that they may handle rails and sections, etc., if necessary.

Forgeability of Iron-Nickel Alloys

Pure Iron-Nickel Alloys Cannot Be Forged Readily at Ordinary Temperatures—Manganese or Titanium Make Alloys Forgeable—Aluminum, Carbon, Manganese or Silicon Have Little Effect.

By T. D. YENSEN,[†]

Research Engineer, Westinghouse Research Laboratory.

In the investigation of the magnetic properties of iron-nickel alloys, it was found necessary in order to make the alloys forgeable, or malleable, to add small quantities of some other element.

Iron-nickel alloys have been known for nearly a century, but have been made in commercial quantities only since 1885. Their remarkable mechanical properties were disclosed by Riley in 1889 and from that time on a large amount of research work has been done both to discover new properties and to correlate the results obtained. Lately the Bureau of Standards has collected the published data in a special circular* giving in compact form an account of the

properties of the iron-nickel alloys. It also contains a clear historical sketch of the development as well as a selected bibliography.

The chief difficulty with the development of iron-nickel alloys was that the "pure" alloys do not forge readily. The addition of small amounts of manganese, however, made the alloys forgeable, and manganese has therefore come to be regarded as a necessary constituent of nickel steels. The present paper shows to what extent manganese is needed for various nickel contents and also what is the effect of other alloying elements on the forgeability. It also touches upon the cause of forgeability but refers to other sources for more exhaustive treatises on the subject.

The alloys were prepared by melting electrolytic iron and electrolytic nickel with or without other

*Invar and Related Nickel Steels, Circular 58, United States Bureau of Standards (1916).

[†]From paper read before February meeting of the American Institute of Mining and Metallurgical Engineers.

alloying elements in the desired proportions in a magnesia crucible in a vacuum furnace under a pressure of 1 mm. mercury. The ingots weighing about 2 kg. were allowed to cool in vacuo. If pipes or blowholes were present, the ingots were cut in such a way as to eliminate them if possible. Other ingots were also cut in order to give separate test pieces for forging at different temperatures.

The ingots, or pieces of ingots, thus prepared were heated in a coke or gas fire to the desired temperature and forged under a power hammer. On account of the oxidizing condition of the coke fire, there is little, if any, contamination by carbon during the heating. Tests have shown that the carbon content of pure iron thus heated is only 0.01 per cent, or practically the same as before. If heated in a gas-fired furnace, the iron may absorb 0.01 per cent. carbon during the heating. However, as far as the forging properties

that is below 600 degrees; dull means 600 to 900 degrees, and bright, temperatures above 900 degrees. These conditions were only estimated by eye, and consequently no great accuracy can be claimed. The forging operation is crude at best, viewed from a scientific standpoint; the temperature begins to decrease as soon as the test piece leaves the fire, and the rate of decrease varies according to (1) the size of the test piece, (2) character of the tongs used, (3) the atmosphere, and (4) the manipulation. Also, the method of forging varies to a large extent; no two blacksmiths will forge alike, and the same blacksmith will forge differently two consecutive test pieces that are alike. In spite of the effort to maintain constant conditions, some variations in the forging quality is undoubtedly due to incidental and personal elements, and on account of the uncertainties thus introduced it would be unwarranted to introduce accurate temperature-measuring devices.

Forgeability of Pure Iron-Nickel Alloys

Up to 7 or 8 per cent. nickel, the forgeability is fairly good at a dull red heat. In the neighborhood of 10 per cent., the forgeability is poor; it is again good for 15 per cent. but poor for 20 per cent., nil for 25, 30 and 35 per cent. (except at a black heat) and up to a high nickel content. Above 75 per cent. nickel, the forgeability is fairly good, and for pure nickel it is good.

The effect of silicon on the forgeability, if any, is very slight. The lower alloys seem to be improved to a slight extent by the addition of 0.2 per cent., but the higher alloys, up to 50 per cent., are unaffected.

Aluminum, carbon and magnesium have no beneficial effect upon the forgeability. If the non-forgeability was due to oxides in the alloys, these elements should have a very beneficial effect because they belong to the strongest deoxidizers known. These results, therefore, indicate definitely that the cause must be of a different character.

Manganese, as was anticipated, makes the alloys forgeable. The 10 per cent. alloy is cured by means of 0.1 per cent. manganese, while the 35 and 50 per cent. alloys require between 0.5 and 1.0 per cent. manganese. A safe formula for 0-50 per cent nickel would, therefore, be:

Per cent. manganese required = 2 per cent. of nickel content.

Of all the different elements tried, titanium has the most beneficial effect upon the forgeability. The amounts required are 0.2 per cent. for 10 per cent. nickel, 0.5 for 36 per cent. nickel, and 0.5 for 50 per cent nickel, indicating that for 0-50 per cent. nickel:

Per cent. of titanium required = 1 per cent. of nickel content.

While this amount will make the alloys forgeable, twice that amount is better. The forgeability of the 10 per cent alloy was perfect at all forging temperatures with 0.2 per cent. titanium added; this was also the case with the 50 per cent alloy with 1.0 per cent titanium added. Consequently a safer formula would be:

Per cent. titanium required = 2 per cent. of iron content.

Specimen No.	Composition					Forgeability					Specimen No.	Composition					Forgeability					Specimen No.	Composition					Forgeability				
	Ni	Mn	Si	Ti		C	Black	Dull	Bright			Ni	Al	C	Mn	Si	Ti	C	Black	Dull	Bright			Ni	Mn	Si	Ti		C	Black	Dull	Bright
2Ni203	1.0										2Ni240	0.0	0.2										2Ni257	50		0.5						
204	1.0		0.2								229	25											258	50		0.7						
207	2.0										230	25					0.2						259	50		1.0						
208	2.0		0.2								240	25						0.2					260	50	0.5							
211	2.8										241	25	0.2										261	50	0.7							
212	2.9		0.2								231	30											262	50	1.0							
213	3.9										277	30											280	50	0.5							
214	3.9		0.2								232	30						0.2					283	50	1.0							
215	4.6										242	30	0.2										2107	50	1.0							
216	4.8		0.2								282	33											2108	50	2.0							
217	5.7										283	33					1.0						263	50	0.5	0.5						
218	5.7		0.2								233	35											264	50	0.5	0.5						
219	7.3										234	35						0.2					269	55	0.5							
220	7.0		0.2								266	36						0.5					284	60	0.5							
221	8.0										2105	35					1.0						278	62	0.5							
223	9.0	0.1									2106	35					2.0						279	62	1.0							
222	10.0	0.1	0.2								265	36					0.5						290	75	0.5							
223	10.0										267	36					0.5						285	76								
227	9.6										268	50					0.1						286	80								
224	10.0		0.2								269	50					0.3						291	90	0.5							
230	9.9										270	50					0.5						292	93	0.5							
225	11.9										260	50							0.2				287	95								
226	15.0		0.2								251	50						0.5					288	100								
247	15.0										252	50							1.0				293	100	0.5							
271	20.0										254	50	0.3																			
248	20.0		0.2								255	50	0.5																			
275	20.0		0.2	0.2																												

Key to Forgeability

Black Not determined

X None

Good

Poor

Fair

Excellent

Fig. 1—Results of tests on forgeability of iron-nickel alloys arranged according to nickel content.

are concerned, such a slight contamination is believed to be insignificant and the alloys will be considered as pure iron-nickel alloys except for the additions subsequently recorded.

In Fig. 1, the alloys have been arranged according to nickel content. In most cases the nickel content was obtained by chemical analysis; in others the added nickel is taken as the nickel content. The figures given for the other elements are the percentages added and not the final composition. In most cases a portion of these elements is lost because of oxidation. The forgeability is visualized by means of shaded squares; the larger the part that is shaded the better is the forging quality.

The forgeability is given for the four conditions: Cold, black heat, dull red, and bright red. Cold means a temperature of 20 to 100 degrees C.; black means any temperature below the appearance of redness,

For nickel contents above 50 per cent. the data is insufficient to be conclusive, but the indications are that the foregoing formulas may be used by substituting "iron content" for "nickel content;" that is, for 50 to 100 per cent. nickel:

Per cent. manganese required = 2 per cent. of iron content.

Per cent. titanium required = 2 per cent. of iron content.

Microscopic Examination

A number of the forgeable and non-forgeable alloys in ingot form were examined under the microscope in order to discover any possible difference in structure that might explain the different behavior under the hammer. While there appears to be a difference in structures between the non-forgeable and forgeable alloys, the difference is not of such a nature as to give any definite answer as to the cause of the variation in the forgeability.

Forgeability Versus Non-Forgeability*

The degree of forgeability depends on the relative strength S_c of the crystals and that of the intercrystalline—or amorphous—material S_i . If the latter is stronger than the former, the crystals will deform when subjected to external forces by slipping along the cleavage planes, and in so doing produce new intercrystalline material along these planes. This, being stronger than the crystals, causes new cleavage planes to be formed with new intercrystalline material, and so on in all directions indefinitely. If, on the other hand, the intercrystalline material is weaker than the crystal faces; in other words, material with this characteristic is not forgeable. The criterion of forgeability, is therefore, that $S_i > S_c$.

As the relation between S_i and S_c varies with the temperature, a certain material may be forgeable at some temperature and not at others. A measure of the deformability—and therefore to a large extent of the forgeability—can be obtained by means of the elongation and reduction of area upon breaking the material in tension, or in other words, by measuring its ductility. Simple test pieces may be prepared from ingot S, castings, or forgings (if available) and tested at various temperatures for elongation and reduction of area. The algebraic mean of these characteristics may then be used as a measure of the forgeability.†

In order to test this relationship, the following samples were selected: "Armco" Iron, 0 per cent. nickel; 2Ni274, 20 per cent. nickel; 2Ni275, 20 per cent. nickel + 0.2 per cent. titanium; 2Ni277, 30 per cent. nickel. 2Ni274 and 277 were not forgeable except below

500 degrees C., and then only with difficulty, while 275 was forgeable at all temperatures. The ingots were cut into small pieces and forged into rods $\frac{1}{2}$ in. (12.7 mm.) in diameter. From these rods, the test pieces were machined having $\frac{1}{2}$ in. threaded ends and a central portion $1\frac{1}{2}$ in. long by $\frac{1}{4}$ in. in diameter. The test pieces were annealed in vacuo at 900 degrees before testing, thus giving the material an opportunity to recrystallize. The testing was done on an Olsen 4,000-lb., hand-operated, testing machine, the test piece being held by special extension rods at the center of a tube electric furnace, capable of heating the test pieces and adjoining holders to a temperature of 1,000 degrees C. The temperature was measured by means of a platinum-platinum-rhodium thermocouple directly touching the center of the test piece while it

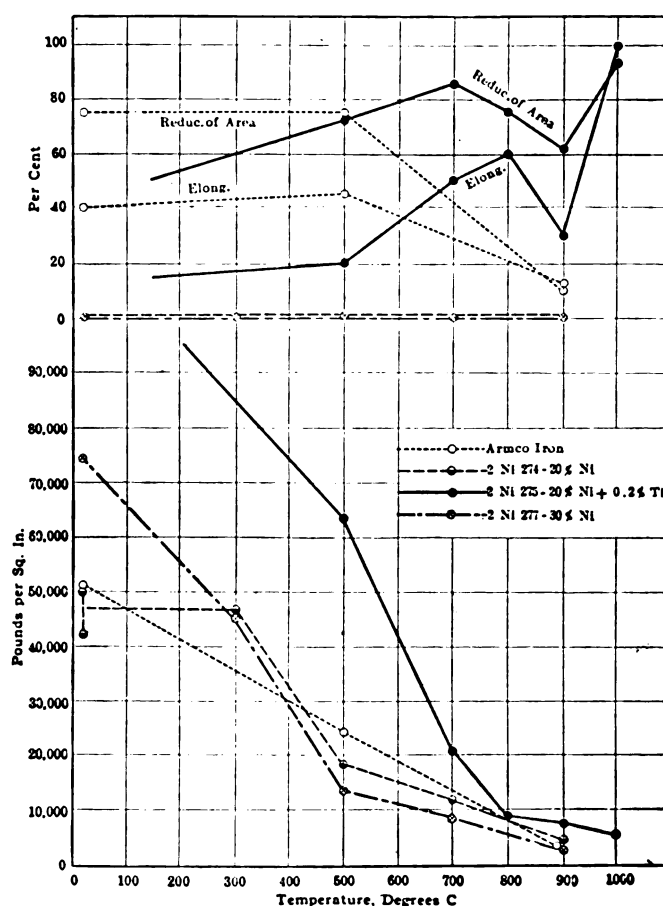


Fig. 2—Results of physical tests of rods forged from ingots.

was being tested, eliminating any possibility of error in obtaining the temperature.

The results are shown in Table 1 and Fig. 2. The "Armco" iron—practically pure iron—shows a linear decrease in strength with increasing temperature, while the ductility remains constant up to 500 degrees, probably higher and drops down to 10 per cent at 900 degrees. The result, therefore, indicates that pure iron should forge well at a dull red heat and below but not at higher temperatures. This indication is confirmed by actual facts.

The two nickel alloys without titanium added have very low ductility at all temperatures, the elongation and reduction of area being so low as to be practically zero. The poor forgeability at all temperatures, and

*Attention is called to the fact that the manuscript of this paper was prepared prior to the appearance of the paper by Dr. Zay Jeffries, "Effect of Temperature, Deformation and Grain Size on the Mechanical Properties of Metals," presented at the February, 1919, meeting. The author refers to this paper, Trans. 1919, 60 474, for discussion of the phenomena taking place in deforming metals. It will be noted that the deductions made in the present paper in regard to the criterion of forgeability agree perfectly with those made by Dr. Jeffries, based on a much more elaborate investigation.

†This theory and deductions were developed in conference with Norman B. Pilling.

Table 1—Mechanical Properties of Iron-Nickel Alloys at Various Temperatures.

Specimen No.	Composition		Test piece No.	Temp. Deg. C.	Yield Point Lb. per Sq. In.	Ultimate Strength Lb. per Sq. In.	Elongation in 1 Inch %	Reduction of Area %
Armco Iron	0	0	1	20		50,500	40.0	75
			2	500	22,400	24,600	45.0	75
			3	900	4,570	4,570	12.5	10
2 Ni 274.....	20	0	A ₁	20	50,000	50,000	nil	nil
			F	20		44,000	nil	nil
			B ₁	300		47,000	nil	nil
			A ₂	500	18,400	18,400	nil	nil
			B ₂	700	12,200	12,200	nil	nil
			C	900	4,600	4,600	nil	nil
2 Ni 275.....	20	0.2	C	20	64,500	> 100,000	Did not break	
			E ₁	500	23,500	63,300	20.0	75
			E ₂	700	10,200	20,400	50.0	86
			F ₁	800		9,200	60.0	75
			F ₂	900	5,100	7,800	30.0	61
			F ₃	1,000	4,100	5,600	100.0	94
2 Ni 277	30	0	A ₁	20	66,500	74,500	nil	nil
			F ₁	300	27,600	45,000	nil	nil
			D	500	13,300	13,300	nil	nil
			E	700	9,200	9,200	nil	nil
			F ₂	900	4,270	4,270	nil	nil

particularly at temperatures above 500 degrees is, therefore, in agreement with these results.

The 20 per cent. alloy with 0.2 per cent. titanium added has widely different characteristics. The strength, while decreasing rapidly with increasing temperature, is much greater and the ductility increases with temperature until, at 1,000 degrees, both elongation and reduction of area are about 100 per cent. The forgeability should, therefore, increase with the temperature, which was found to be the case, although the alloy forged very well at all temperatures. The 0.2 per cent. titanium has, therefore, entirely changed the characteristics of the 20 per cent. alloy, probably by strengthening the intercrystalline material relatively to that of the crystals.

Summary and Conclusion

1. Pure iron-nickel alloys do not forge readily, if at all, at ordinary forging temperatures.
2. Aluminum, carbon, magnesium, or silicon have

little or no effect upon the forgeability.

3. Manganese or titanium in amounts of 2 per cent. of the lesser constituent make the alloy forgeable.

4. Whereas the degree of forgeability of a material depends on the relative strength of the crystalline and the intercrystalline—or amorphous—material, the forgeability of an ingot or casting can be ascertained only by actually attempting to deform the material, either by forging or rolling, or by a tensile test. Metallography has not yet reached a stage where an inspection of the microstructure will give any definite information in this respect.

5. The fact that manganese and titanium transform iron-nickel alloys from non-forgeable to forgeable alloys means that these elements have the ability to strengthen the amorphous material that is generated between the crystals to such an extent as to make it stronger than crystalline material.

Heating Furnaces and Annealing Furnaces

Fuel Oil—Advantages and Disadvantages—Heat Value, Specific Gravity and Viscosity—Leading Principles in Spray Burners and Vaporizers—Interdependence of Burner Size and Flue Size.

By W. TRINKS.
PART XVI.

IN turning our attention from gaseous fuels to liquid fuels, it behooves us to study the properties of fuel oil and the appliances for its economical combustion.

Fuel oil has many advantages. It can readily be stored above or below ground, and in out-of-the-way places. In that respect it not only shares the convenience of coal as fuel, but goes far ahead of it. Fuel oil is always ready to serve, just like natural gas or city gas. But it is even more ready to serve, because natural gas is frequently shut off in cold weather. There are no standby losses with oil such as are in-

evitable with gas producers, water gas plants, or any other equipment for the generation of an industrial gas. Fuel oil has almost all of the advantages of gaseous fuels. In particular, it allows the use of any desired number of burners for a given furnace, which fact results in uniform temperature throughout the furnace. Like gas, it lessens labor compared to coal, there being no ashes to handle and no fires to clean. The simplicity of an oil-burning installation is well illustrated by Fig. 105. (W. S. Rockell Company).

With so many good properties oil would be the universal furnace fuel if its price were low enough.

Unfortunately, the price fluctuates violently, and has, within the last few years, ranged between 3 cents and 15 cents a gallon, with a tendency to climb still higher. Since a gallon of fuel oil develops approximately 144,000 Btu, the price of 1,000,000 btu will range from \$0.21 to \$1.05. Coal at \$3 per short ton and of 13,500 btu per pound calorific values, cost 11 cents for 1,000,000 btu. The difference in price is sufficient to assign

general properties should be mentioned. In the United States, fuel oil is almost invariably crude oil (petroleum) from which lighter oils such as gasoline, naphtha, and kerosene have been removed. The composition of fuel oils varies greatly, depending upon their origin (Pennsylvania, California, Texas, Oklahoma, or Mexico) and upon the degree to which the distillation has been carried. The heat value per pound varies

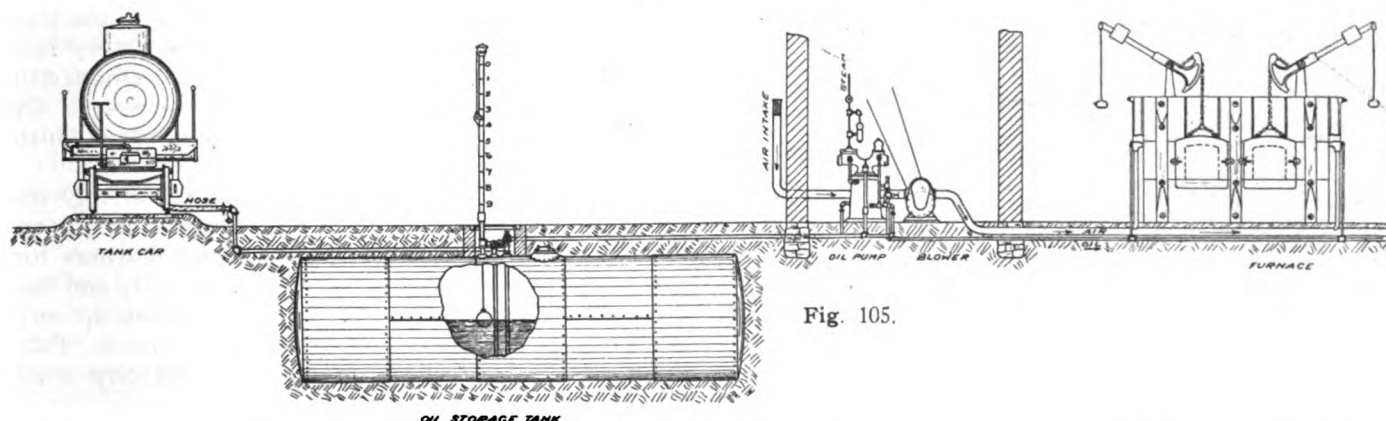


Fig. 105.

a definite field to oil. Its use will always be general near the oil fields, and in places to which it can be transported at very small expense or, at least, at an expense which is small compared to that of transportation of coal. In all other localities it will be limited to those furnaces in which the above cited advantages overbalance the question of price.

Before the combustion of oil is studied some of its

from 18,900 to 20,000 btu., while the heat value per gallon varies from 151,000 to 134,000 btu. The heavier Mexican oils have the smaller heat value per pound, and the greater heat value per gallon. In the properties of fuel oils their specific gravity plays an important part. The heavier Mexican oils have a specific gravity of from .9 to .97 (25 to 14 degrees Beaume) while the fuel oils from eastern fields have a density

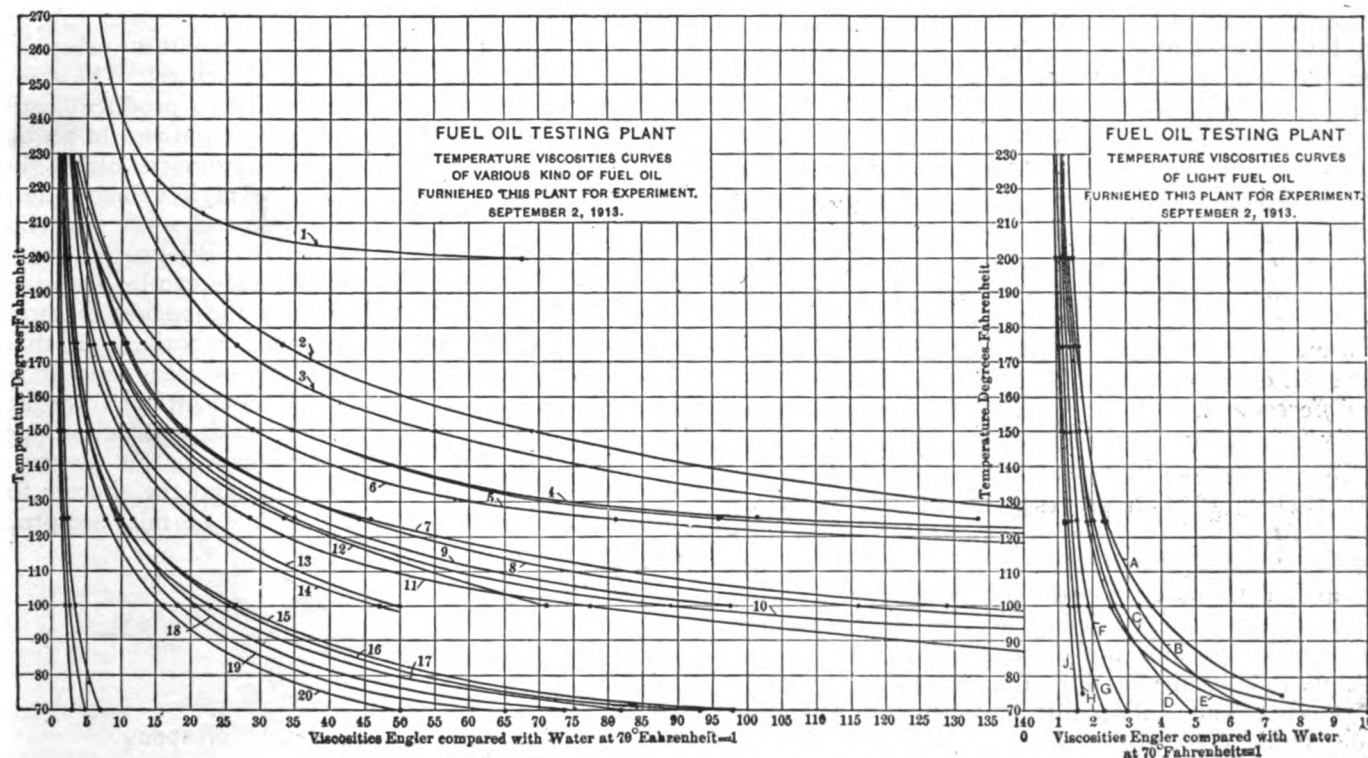


Fig. 106—Viscosities of oils at various temperatures. (Notation for curves.)

(1) Mexican Residue, 10° B. 374° F. Flash (open cup). (2) "Toltec Fuel Oil," Inter-Ocean Oil Company, New York, 11.7° B. 228° F. Flash. (3) "Toltec or Panuco Oil," Inter-Ocean Oil Company, 12° B. 124° F. Flash. (4) "No. 18," Union Oil Company, Bakersville, Cal., 12.9° B. 285° F. Flash. (5) "No. 102," Union Oil Company, Bakersville, Cal., 12.9° B. 280° F. Flash. (6) "No. 25," Union Oil Company, Bakersville, Cal., 13.2° B. 262° F. Flash. (7) "Standard" Mexican Crude, 15.4° B. 202° F. Flash. Lot No. 2. (8) Texas Company's Mexican Crude, 17.3° B. 126° F. Flash. (9) Sample No. 3, Anglo-Mexican Petroleum Products Company, 17.3° B. 164° F. Flash. (10) "Gaviota Refinery" Associated Oil Company, Cal., 17.1° B. 230° F. Flash. (11) Sample No. 2, Anglo-Mexican Petroleum Products Company, 16.2° B. 238° F.

of from .80 to .84 (44 to 37 degrees Beaume). The viscosity of the oil varies with the density, the light oils being more fluid than the heavy oils at one and

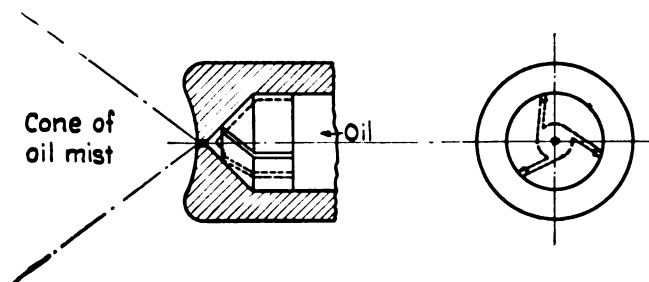


Fig. 107—Typical oil atomizer using oil pressure only.

the same temperature. However, there is no definite connection between density and viscosity, oils of the same density but of different origin frequently having different viscosities. The latter property, as will be seen later, is of tremendous importance for the combustion of oil, but it requires a delicate instrument for its determination. On the other hand, the degrees Beaume (which express the specific gravity) can easily be measured with a hydrometer. This fact coupled with the general, although indeterminate relation between viscosity and specific gravity has given rise to the general custom of describing an oil by its density rather than by its viscosity.

Viscosity, or internal friction, or resistance to the relative motion of the particles, is the opposite of fluidity. As temperature grows, fluidity of all oils grows, that is to say, the viscosity drops. The relation between temperature and viscosity for many oils used in the United States is given by the curve sheet Fig. 106. The data for the curve sheet were taken from the tests made by the U. S. N. Fuel Testing Plant.

Oil rarely, if ever, burns as a liquid; almost invariably it is the oil vapor which burns, because the kindling temperature of oil lies far above its vaporization temperature. If an attempt is made to burn liquid oil, the vapor of the oil burns at the surface just as fast as it can find oxygen. The combustion is then a surface action. If, on the other hand, an oil vapor can be formed, and can be mixed with air, mass action will result during the combustion. In accordance with the difference, we find two methods of combustion, namely (1) combustion by surface action (atomization) and (2) combustion by mass action (vaporization).

In the atomization process, the guiding principle is this: Atomization (disintegration, or pulverization) must be fine enough to insure complete combustion before any oil drops on a solid substance (such as the hearth or the material being heated) or before the drops are swept into the discharge flue. From this principle follows that a short flame requires very fine pulverization and a thorough admixture of air, while a long flame does not require fargoing atomization.

Atomization is obtained by (1) oil pressure and whirling, (2) shredding action of a high-velocity fluid.

In the first method (pressure atomization in "mechanical" burners) the oil passes through a very fine orifice with a high velocity both of translation and ro-

tation, see Fig. 107. A cone of oil mist results, the fineness of subdivision depends upon the pressure in the oil, and upon its viscosity, both in conjunction with the size and the smoothness of the orifice. Very thin oils can be sprayed with 30 to 40 pounds per square inch pressure, whereas heavier oils require up to 200 pounds per square inch pressure. The very heavy oils require considerable heating even at that high pressure.

Referring back to Fig. 107, it should be noted that the illustration is diagrammatic only. The rotary motion which breaks up the oil stream can be imparted to the oil by various rotation producing devices. Or the oil can be impinged on to a knife edge which breaks it up.

Mechanical atomization is used comparatively little in heating furnaces and in annealing furnace practice because it is difficult to make good burners for small capacity, except with thin, clean oils, and because the small orifices in the burner tips clog up very easily, unless very efficient strainers are used. Furthermore, it is difficult to regulate the quantity of oil going through a burner, because the same reduction of oil pressure which diminishes the oil flow also results in coarser drops of oil. The advantage of mechanical atomization is that neither steam nor air is needed. If the use of steam is to be avoided altogether, both the pumping and the heating of the oil must be done electrically.

In the second method, namely atomization by the shredding action of a fluid flowing at high velocity, such as air or steam, the latter passing over the surface of large oil drops wipes off small particules and carries them along into the combustion space. Again, thin oils are well atomized by medium velocities, while thick oils require greater velocities. The steam or air pressure which is necessary to produce "satisfactory" atomization, cannot be determined in an off-hand way, because most atomizing devices utilize, besides the shredding action of a high velocity fluid, some atomization by oil pressure and some vaporization by incandescent refractories. By proper use of the latter two agents the air pressure can be decreased to almost nothing, in which case the burner is purely an oil pressure atomizer or even a vaporizer. If short flames, say 18 to 20 inches are desired (and if oil pressure, and vaporization by hot surfaces are not utilized), the air pressure must reach two pounds per square inch. The higher the steam or air pressure, the lower the oil pressure can be, and the shorter the flame will be (provided that air and oil mist are properly mixed).

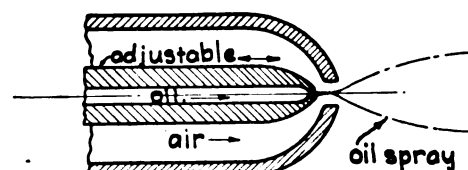


Fig. 108.

The statement is occasionally made that oil can be properly atomized with very low oil pressure and with very low air pressure. Any statement of that

kind is not based on facts, and whenever good combustion is obtained with low pressures, it will be found that the oil was largely vaporized, as described further down, but not atomized.

The number of atomizers in existence is very great and is increasing daily. The general principle is shown in Fig. 108. Oil passes through an orifice or nozzle with 5 to 15 feet per second velocity into a current of rapidly flowing air. The rate of oil flow is regulated by a valve outside the atomizer, while the rate of air flow is regulated by moving the center core to the right or left. In that manner the velocity of the atomizing air is kept constant, and the atomizing action is maintained down to very low rates of oil flow. This principle is important and can, of course, be carried out by many other designs besides the one shown in Fig. 108.

Gasification or vaporization of the oil is obtained either by preheating the oil or else by letting the oil flow into highly preheated air when it at once flashes into vapor. Preheating of oil has its limitations because of the cracking of the oil and of subsequent carbonization. The thinner oils can be preheated to vaporization without cracking, but the heavier oils will carbonize before they are vaporized. It is probably quite safe to preheat the oil to 500 to 550 degrees F., and then to let it be picked up by a current of air, having a temperature of 700 to 1,000 degrees F. With vaporizing apparatus, the starting of a cold furnace is more inconvenient and more productive of smoke than it is with atomizing apparatus.

The principle of oil vaporization is illustrated in Fig. 109. Hot oil, almost ready to flash vapor flows into a current of still hotter air. The mixture flows into a combustion chamber, which is surrounded by red-hot refractories, and in which the vaporization is completed.

With either type of equipment, it is very difficult to secure the correct to air ratio, or in other words, to secure perfect combustion with practically no excess air. It will be remembered that a similar difficulty arises with gaseous fuel, but conditions are much more complicated with oil fuel, on account of the effects of viscosity.

With gaseous fuel, the quantities flowing remain sensibly constant, as long as the driving pressures remain constant, because changes of temperature up to 20 or 30 degrees F. have but little effect. But with

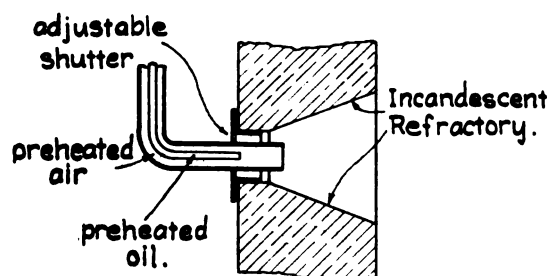


Fig. 109.

oil fuel, the same change of temperature produces such a change of fluidity (see Fig. 106) that the quantity of oil flowing into the furnace is changed by a very

considerable amount. Any device for automatic regulation of combustion of fuel oil, to be anywhere near correct, must include a thermostatic control of oil

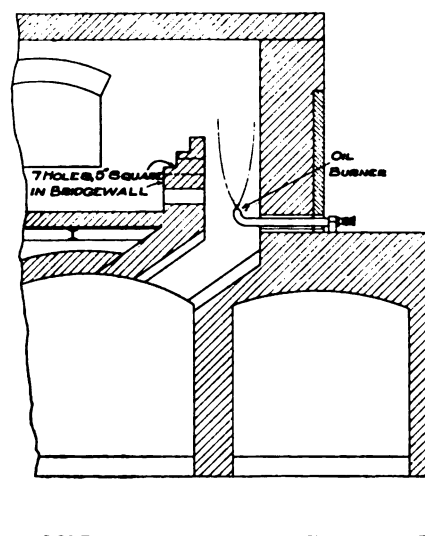


Fig. 110.

temperature. The complication which arises from using a complete regulating device is so great that the latter is seldom, if ever, used. It is then left to the heater to adjust oil and air by the color and smokiness of the flame resp. combustion gases. In consequence, oil furnaces very often work with large amounts of excess air, and excess air involves a loss.

Hydrocarbons break up at high temperatures and this is particularly true of the heavy hydrocarbons which constitute fuel oil. If sufficient oxygen for immediate combustion is not present, the flame is exceedingly luminous ("rash," as the heaters call it) or if the deficiency of oxygen is very great, it is exceedingly smoky. In consequence, oil flames cannot be used in annealing operations in the same manner in which the flames of natural gas, producer gas, or water gas are used. The pieces which are to be annealed, must to a certain extent, be screened from the bright radiation of the flame. An arrangement of this nature for a regenerative annealing furnace is shown in Fig. 110. (Installation made by Tate-Jones Company.)

It has been stated that there is no such thing as an oil burner, but that any equipment bearing that name serves a purely mechanical purpose, namely, that of atomization. Any such statement overlooks the fact that the thorough mixing of the atomized oil and the combustion air is likewise a function of a good burner. It must be admitted that there are cases where the so-called burner can do nothing besides spraying toward a thorough mixing of the oil mist and air; this is particularly true whenever the oil comes from a regenerator, as in the illustration, Fig. 110. Finally, arrangements for the control of flow of oil and air form part of a burner. Means for regulation of the air supply and for observation of the flame are absolutely essential.

In this connection, it should be mentioned that many of the atomizing or "sprayer" burners make use of the injector action of the steam or air jet for the purpose of including the necessary air for combus-

tion of the oil spray. The advantage of a high steam or air pressure used in the production of the jet is that a pressure up to 1/10-inch of water can be produced in the furnace so that stacks for the removal of the products of combustion become unnecessary. But the advantage can readily be turned into a disadvantage, because the amount of air which is induced varies greatly with the furnace pressure. If the burner is run light, the furnace pressure is low, and the ten-

dency is to draw in much more air than is needed for combustion. If the burner is forced, the products of combustion find difficulty to escape, the furnace pressure rises, not enough air is induced to maintain proper combustion of the increased oil vapor volume, and the flame becomes terribly smoky. It requires great care and experience to so balance burner design and flue design that combustion remains perfect, without excess or deficiency of air, over a wide range of oil delivery.

Physical Changes in Iron and Steel Below the Thermal Critical Range.

Effect of Permanent Deformation of Iron and Steel in the Blue Heat Range—Thermal and Electrical Conductivities—Effect of Quenching Nickel-Chromium Steels on Resistance to Impact.

By ZAY JEFFRIES.†

IT has been known for centuries that iron and steel could be hardened by cold hammering and that the metal could be restored to the normal condition by heating to a red heat and cooling either rapidly or slowly with nearly pure iron and slowly with steels containing considerable carbon. The art of tempering steels is also very old. When a medium or high-carbon steel is quenched from a cherry-red heat, the hardness is increased; this hardness can be reduced by heating to various temperatures below the lower thermal critical point, which is near 700 degrees C. The present paper will not consider these old and well-known changes in iron and steel below the thermal critical range but will confine itself to the more unusual changes, some of which have been studied recently. Stromeier,¹ for example, in 1886, reports that both working steel and heat treatment of steel in the blue-heat range are highly injurious. Recently, however, some metallurgists believe that the straightening of warped steel forgings at a blue heat produces a beneficial effect on the metal.²

The Engineering Division of the National Research Council has constituted a committee on Physical Changes in Iron and Steel Below the Thermal Critical Range, which has the following personnel: R. R. Abbott, H. C. Boynton, William Campbell, J. V. Emmons, F. B. Foley, H. J. French, H. M. Howe, Zay Jeffries (chairman), F. C. Langenberg, J. A. Mathews, P. D. Merica, A. H. Miller, J. H. Nelson, G. A. Reinhardt, W. E. Ruder, H. F. Wood. This committee is studying several aspects of the physical changes in iron and steel. The results, reported in the literature and obtained by recent experimentation, will be given; this will be followed by a general theoretical discussion of

the more important observations outlined. Finally, the commercial importance of this subject will be briefly considered.

Tensile Properties of Iron and Steel Below the Thermal Critical Range.

The tensile strength of nearly pure iron, such as Armco iron or wrought iron, is about 40,000 to 50,000 pounds per square inch (2,812 to 3,515 kg per square cm) at room temperature. The strength increases with rising temperature up to about 200 degrees to 250 degrees C.; the maximum strength is usually 15 to 25 per cent, and in one instance 37.6 per cent,³ greater than that at room temperature. The strength increases gradually, from a minimum, throughout a temperature range of about 200 degrees C. and then decreases gradually for an additional 100 degrees C.; after this, the rate of decrease of strength with increase in temperature becomes rapid. These results are reported by Martens,⁴ Speiler,⁵ Epps and Jones,⁶ Lea and Crowther,⁶ Bach,⁷ and Howard.⁸ The tensile properties of Armco iron, with the exception of the elastic limit, are given in another communication by the present author.⁹ In Howard's work, the tensile properties of steels with varying carbon content are

³F. A. Epps and E. O. Jones: Influence of High Temperature upon Elastic and Tensile Properties of Wrought Iron. *Met. and Chem. Engng.* (1917) 17, 67.

⁴Martens: Influence of Heat on the Strength of Iron. *Proc. Inst. Civil Engrs.* (1890-91) 104, 209.

⁵F. N. Speller: Discussion of Recrystallization as a Factor in the Failure of Boiler Tubes. *Proc. Amer. Soc. Test. Mat.* (1916) Pt. 2, 112.

⁶F. C. Lea and O. H. Crowther: Change of the Modulus of Elasticity and of the Other Properties of Metals with Temperature. *Engng.* (1914). 98, 487.

⁷C. Bach: Versuche über die Verschiedenheit der Elastizität von Fein- und Morison-Wellrohren. *Zeit. Ver. deut. Ing.* (1904) 48, 1,227; Versuche über die Festigkeit seigenschaft von Flusseisenblechen, etc. *Ibid.* (1904) 48, 1,342.

⁸J. E. Howard: Physical Properties of Iron and Steel at Higher Temperature. *Iron Age* (1890) 45, 585.

⁹Zay Jeffries: *Trans. A. I. M. E.* (1919), 60, 474.

¹C. E. Stromeier: Injurious Effect of a Blue Heat on Steel and Iron. *Proc. Inst. Civil Engrs.* (1885-86) 84, 114.

²F. C. Langenberg: Private communication.

†Paper read before February meeting of the American Institute of Mining and Metallurgical Engineers.

given. He gives the tensile strengths of steels containing 0.09, 0.20, 0.37, 0.57, and 0.97 per cent carbons, all of which show gradual increase up to 250 degrees to 300 degrees C. It seems that the greater the carbon content, the greater is the magnitude of the increase; but the high-carbon steels do not necessarily show as large an increase in percentage of strength as the low-carbon steels.

The elastic limit of iron and steel at elevated temperatures is reported, by Martens, to be the same at 250 degrees C. as at room temperature, passing through a maximum at about 200 degrees C. Howard, on the other hand, states that the elastic limit of steel decreases continuously with a rise in temperature. Huntington¹⁰ gives elastic-limit determinations at elevated temperatures on wrought iron and mild steel, and although some of the points indicated at temperatures above the ordinary are higher than the room-temperature values, the curve that he draws does not pass through a maximum value. The decrease plotted by his own curve, however, is not in accordance with the decrease expected with an increase in temperature, but indicates a discontinuity. Recently, H. J. French, of the U. S. Bureau of Standards, has determined carefully the elastic limit as well as other tensile properties of mild steel and checks Marten's results; the elastic limit is about the same at 250 degrees C. as at room temperature and it passes through a maximum value of 200 degrees C. about 15 per cent greater than at room temperature. Epps and Jones report a 10 per cent increase in wrought iron in the corresponding temperature range. Notwithstanding the report by Howard, in 1890, that the elastic limit of iron and steel decreases with a rise in temperature, the evidence to the effect that the elastic limit in iron and mild steel is greater at 200 degrees C. than at room temperature is overwhelming. That this is true in medium and high-carbon steels is not certain.

The elongation of iron and mild steel decreases above room temperature and passes through a minimum between 100 degrees and 300 degrees C. and then increases up to 500 degrees C. The elongation at 500 degrees C. is greater than that at room temperature. Epps and Jones report minima elongation values in wrought iron at 100 degrees to 150 degrees C. and 500 to 550 degrees C. and a maximum at about 300 degrees C.; this decrease above 300 degrees C. does not seem to be the rule.

The reduction of area of iron and mild steel seems to increase at temperatures slightly above room temperature and then decreases, passing through a minimum about 300 degrees C., and then increases up to about 500 degrees C. Above 500 degrees C., the elongation and reduction of area both vary markedly with grain size and the rate of loading. The effect of liquid-air temperature (about 190 degrees C.) on iron and steel is to greatly increase the strength and decrease ductility.¹¹

¹⁰A. K. Huntington: Effect of Temperature on Tensile Tests of Copper and its Alloys. *Jnl. Inst. Met.* (1912) 8, 126.

¹¹R. A. Hadfield: Alloys of Iron and Tungsten. *Jnl. Iron and Steel Inst.* (1903) 64, 14.

Recovery of Elasticity of Iron and Steel After Over-strain.

Prof. H. M. Howe has called attention to the fact¹² that recently deformed mild steel loses its elasticity. The effect of rest at room temperature is to slowly restore the elasticity and eventually to raise it above the load that caused the previous deformation. The effect of warming is to greatly hasten the recover of elasticity. J. Muir,¹³ in three papers, discusses in detail the elastic recovery of recently overstrained steel. He reports that the recovery of elasticity at 100 degrees C. is as pronounced after three or four minutes as in two weeks at room temperature. In the mild-steel samples with which he worked, he found no change in elastic properties in the material in its original state, after boiling in water or after heating to 250 degrees C. After slightly deforming by tension, however, the material almost lost entirely its elasticity and recovered it very gradually, the complete recovery being effected in about two weeks. If the material is allowed to rest at a low temperature, say around 0 degrees C., the recovery is much impeded or totally destroyed.¹⁴

Muir found that steel containing about 0.2 per cent carbon recently quenched from a red heat was imperfectly elastic when tested immediately, but when deformed in this state it immediately became perfectly elastic, up to the load that produced the deformation.

Effect of Permanent Deformation of Iron and Steel in the Blue-heat Range.

As mentioned above, Stromeyer warns against the working of steel in the blue-heat range because it produces brittleness. Howe¹⁵ calls attention to the fact that steel bent at blue heat is stronger than steel bent a like amount at ordinary temperature. Howard gives the following quantitative information on a steel containing 0.97 per cent carbon; its elastic limit at room temperature was 82,000 pounds per square inch (5,764 kg per square cm) and the tensile strength was 154,000 pounds per square inch (10,826 kg per square cm). When stressed to 140,000 pounds per square inch (9,842 kg per square cm) at a temperature of 535 degrees F. (279 degrees C.) and broken at 70 degrees F. three days later it showed an elastic limit of 164,000 pounds per square inch (11,529 kg per square cm) and a tensile strength of 167,000 pounds per square inch (11,740 kg per square cm). Its normal elastic limit at the temperature of deformation was 64,000 pounds per square inch (4,499 kg per square cm).

The present author has made tests on blue-heat deformation of Armco iron and has compared the tensile properties of both at ordinary and at elevated temperatures. The following conclusions are made from this work:

1. Armco iron deformed at room temperature a given amount does not increase as much in tensile strength as when deformed the same amount at blue heat.

¹²"Metallurgy of Steel," 212. N. Y., 1890.

¹³J. Muir: On the Overstraining of Iron. *Phil. Trans. Roy. Soc. London* (1900) A193, 1; *Ibid.*, A198, 1; *Proc. Roy. Soc. London* (1906) A77, 277.

¹⁴W. A. Scoble: Report on Combined Stress. *Brit. Assn for Adv. of Sci.* (1913) Sec. G.

¹⁵Op. cit., 234.

2. When Armco iron is drawn cold, its tensile strength at 200 degrees to 300 degrees C. is greater than at room temperature with moderate reductions by drawing; but with 96 per cent reduction of area by cold drawing, the tensile strength is greater at room temperature than at any higher temperature. The tensile strength-temperature curve, however, shows clearly that it passes through a change point inasmuch as the strength does not decrease as rapidly from 15 degrees to 300 degrees C. as from 300 degrees up. The decrease in strength is also much more rapid from -190 degrees C. (liquid-air temperature) to 15 degrees than from 15 degrees to 300 degrees C.

3. The effect of drawing Armco iron wire at 200 degrees to 400 degrees C. is to produce greater tensile strength at all temperatures up to 550 degrees C. than would obtain with the same amount of deformation in the cold. The elongation is less after drawing at 200 degrees to 400 degrees C. than after drawing the same amount at room temperature. The same conclusion is true in general of the reduction of area.

The results given by W. E. Ruder,¹⁶ in Table 1, show the effect of rolling cold and at various elevated temperatures on the strength of mild steel. His results on a nickel-chromium steel in the annealed condition are given in Table 2.

Table 1—Effect of Rolling Hot and Cold on the Tensile Strength of Mild Steel.

	Ultimate Strength, Lb. per Sq. In.
0.192 in. diameter.....	58,200
Annealed	55,200
0.192 in. diameter.....	67,000
Reduced to 0.179 in. cold.....	69,500
0.192 in. diameter.....	110,200
Reduced to 0.179 in. at 240° C.....	112,300
0.192 in. diameter.....	112,700
Reduced to 0.179 in. at 300° C.....	113,500
0.192 in. diameter.....	114,100
Reduced to 0.179 in. at 400° C.....	105,300

Table 2—Method of Treatment.

	Tensile Strength, Lb. per Sq. In.	Yield Point, Lb. per Sq. In.	Per Cent Elongation, 2 In.
Annealed	101,500	67,100	25.5
Annealed, then reduced 10 per cent at 300° C..	137,600	132,500	10.5
Heat treated and reduced 10 per cent at 300° C..	199,100	163,700	7.5
Annealed and reduced 10 per cent cold.....	114,200	102,000	19.5

Effect of Aging on Tensile Properties of Heat-treated Medium-carbon Steel.

Reinhardt and Cutler¹⁷ found that steels containing 0.35 to 0.45 per cent carbon gave no trouble in obtaining the necessary physical properties when the samples were machined and tested immediately after heat treatment; but in steels containing carbon between 0.49 and 0.55 per cent, the tests taken from billets 5¾ inches (14.6 cm) square showed inferior elongation and reduction of area if tested immediately after heat treatment and machining, whereas after resting at room temperature for even 12 to 24 hours the results

¹⁶Private communication, May 28, 1918.

¹⁷G. A. Reinhardt and H. L. Cutler: Effect of Time and Low Temperature on Physical Properties of Medium-carbon Steel. Bull. 151 (July, 1919) 1,091.

were increased sometimes more than 100 per cent. Heating to 120 degrees C. effected this increase more quickly than room-temperature aging. Test bars turned from ingots of steel having the same chemical composition rolled to 1¾-inch square billets did not show the inferior values in elongation and reduction of area immediately after treatment. From the tabulated data given by Reinhardt and Cutler, it would seem that complete restoration of ductility takes place in about 25 hours at 120 degrees C. and in about 16 days at room temperature. It should be noted that this aging effect is not associated with previous plastic deformation and, consequently, is a different phenomenon from the recovery of elasticity after over-strain. That aging was necessary to increase the ductility of forgings has been known, or at least suspected, for many years but the results given by Reinhardt and Cutler give unquestionable quantitative evidence on this subject.

Thermal Critical Points Below A₁.

Cloupe¹⁸ reports an evolution of heat on rise of temperature in all steels that have previously undergone cold working or heat treatment. The point occurs at about 400 degrees C. in all cases and is not reversible. Honda¹⁹ reports that there is strong evidence of the existence of an allotropic point at 215 degrees C. in steel, which is missing in pure iron, as is the A₁ point. He finds in cementite a marked magnetic transformation at 215 degrees C., which is reversible. He finds the same point in steels containing 1.5, 1.02, 0.80, 0.64, and 0.18 per cent carbon. The magnitude of the transformation decreases as the carbon content is lowered and is zero in pure iron. He also finds transformations at both 400 degrees and 215 degrees C. in annealed tungsten steel, indicating a transformation in another carbide at 400 degrees C. Doctor Mathews²⁰ reports a thermal change in nickel-chromium steel below the A₁ point.

Surface Deformation in Steels Quenched from Blue Heat.

Zschokke²¹ found that on heating a square gage of steel to a temperature between 225 degrees and 400 degrees C. and quenching in water, the polished face became plaited or folded so that the markings could be observed macroscopically. Bogitch²² has studied this phenomenon more completely. The formation of this folding on the polished surfaces of steel depends on several factors as follows:

1. Quenching in boiling water does not deform the polished surface. On the other hand, on quenching in iced water or salt water at -18 degrees C. the range of folding is slightly widened.

¹⁸F. Cloupe: Trempe et Ecouissage des Aciers au Carbone. Compt. Rend. (1918) 166, 415; Jnl. Amer. Soc. Mech. Engrs. (1918) 40, 500.

¹⁹K. Honda: On Magnetic Analysis as a Means of Studying the Structure of Iron Alloys. Jnl. Iron and Steel Inst. (1918), 98, 375.

²⁰Private communication.

²¹B. Zschokke: L'influence des Brusques Changements de Temperature sur l'acier Doux. Rev. de Met., Mem. (1910) 7, 165.

²²B. Bogitch: Sur les Deformations Superficielles des Aciers Tempes aux Temperatures Peu Elevees. Compt. Rend. (1915) 160, 768.

2. At each quenching temperature, a definite type of marking or folding is obtained if the conditions of quenching mentioned are adhered to. For each quenching temperature all the types of markings corresponding to lower temperatures may be obtained by diminishing the duration of heating.

3. The piece of steel once quenched loses, at least partly, its ability to form these markings or foldings. It is necessary to anneal above 700 degrees C. to cause it to regain this property.

4. When progressively smaller gages of the same thickness are quenched, the quenching temperature range within which the folds are observed diminishes until it disappears with the gage 1 cm on a side.

Thermal and Electrical Conductivities of Iron and Steel.

Two papers by Honda and Simidu,²³ on the thermal and electrical conductivities of carbon steels at high temperatures show an irregular change in the heat conductivities of carbon steels containing from 0.18 to 1.5 per cent carbon. The decrease in conductivity is not marked until a temperature near 300 degrees to 400 degrees C. is reached, after which it decreases quite rapidly with temperature. The thermal conductivity of Swedish iron decreases more uniformly from room temperature to 500 degrees C., but one point lies off the smooth curve at the temperature of 234 degrees C. The steel containing 1.02 per cent. carbon actually has higher thermal conductivity at 250 degrees C. than at room temperature and several of the readings in the low-temperature range do not lie on a smooth continuous curve.

Table 3—Analyses of Steels.

	Steel			
	H57	C4	C5	C7
Carbon, per cent.....	0.57	0.76	0.945	1.05
Manganese, per cent.....	0.11	0.221	0.189	0.190
Phosphorus, per cent.....	0.010	0.016	0.013	0.013
Sulphur, per cent.....	0.020	0.041	0.016	0.020
Silicon, per cent.....	0.17	0.169	0.155	0.167

Table 4—Effect of Tempering on Specific Resistivity.

	Steel			
	H57	C4	C5	C7
Carbon, per cent.....	0.57	0.76	0.945	1.05
Specific resistivity:				
When quenched from 907° C.....	21.88	32.24	36.32	39.73
On tempering 1 hour at 100° C.				
to 108° C.....	20.67	27.47	29.62	32.97
On tempering 1 additional hour at 100° C. to 108° C.....	20.54	27.47	29.12	32.18
On tempering 2 additional hours at 100° C. to 108° C.....	20.54	27.07	28.89	31.58
On tempering 3 additional hours at 100° C. to 108° C.....	20.27	26.55	28.27	30.32
On tempering 6 additional hours at 100° C. to 108° C.....	19.87	25.75	27.31	29.19
Total drop in 12 hours tempering..	2.01	6.50	9.01	10.54

The electrical resistivities of Swedish iron and carbon steel show smooth curves with uniform slope with the exception of steels containing 1.02 per cent and 1.3 per cent carbon, which have points lying off the smooth curves in the temperature range 175 degrees to 275 degrees C. Meyer²⁴ gives electrical-resistivity curves of pure iron showing slight discontinuities in the blue-heat range. Prof. E. D. Campbell²⁵ shows

²³K. Honda and Takeo Simidu: Sci. Repts., Tokoku Univ.

²⁴A. R. Meyer: Ber. deut. phys. Gesell. (1911) 9, 680.

²⁵E. D. Campbell: On the Rate of Change at 100° C. and at Ordinary Temperatures in the Electrical Resistance of Hardened Steel. Jnl. Iron and Steel Inst. (1918) 98, 421.

that the electrical resistivity of hardened steel decreases with rest at ordinary temperatures and much more rapidly at 100 degrees C. Tables 3, 4, and 5 give the complete data on his experiments.

Curves are shown in the original paper. The change of electrical resistivity at ordinary temperatures after two years is only from about 35 per cent to a little more than 40 per cent of that produced in 12 hours at 100 degrees C. The work of Barus and

Table 5

	Steel			
	H57	C4	C5	C7
Carbon, per cent.....	0.57	0.76	0.945	1.05
Specific resistivity:				
When quenched from 906° C.....	21.07	32.64	35.85	40.00
After standing 7 days at room temperature	21.17	32.48	35.53	39.87
After 14 days.....	21.21	32.45	35.50	39.80
After 21 days.....	21.11	32.31	35.22	39.67
After 28 days.....	21.17	32.24	35.12	39.33
After 2 months.....	21.01	31.78	34.50	38.99
After 3 months.....	20.94	31.18	34.10	38.32
After 4 months.....	20.84	31.05	33.70	37.76
After 6 months.....	20.94	31.02	33.70	37.76
After 9 months.....	20.82	30.71	33.24	37.27
After 12 months.....	20.87	30.83	33.24	37.27
After 18 months.....	20.87	30.55	32.87	
After 24 months.....	20.60	30.33	32.53	36.47
Total drop in specific resistivity in 24 months at room temperature..	0.47	2.31	3.32	3.53

Strouhal²⁶ shows that with a rise of temperature above 100 degrees C., the rate of decrease of electrical resistivity is much accelerated.

Spontaneous Generation of Heat and Spontaneous Contraction in Recently Hardened Steel.

When J. E. Howard²⁷ attempted to determine the coefficient of expansion of hardened high-carbon steel, he found an abnormally low result, which was explained after remeasuring the length at the low temperature. It was found that the steel had permanently contracted in length and obviously the rise in temperature had greatly hastened this change in volume. Charles F. Brush²⁸ reports the spontaneous generation of heat and spontaneous contraction in recently hardened high-carbon steel and high-speed steel at room temperature. In Brush's first experiments, an evolution of heat only was noted and the apparatus he devised was so sensitive that the heat evolution could still be detected after five weeks. Later experiments on a nickel-chromium steel, furnished by Sir Robert Hadfield, showed a spontaneous absorption of heat if quenched during the rise of temperature between 530 degrees and 667 degrees C., but an evolution of heat if quenched on falling temperature. These results are all summarized together, with additional data in a paper by Brush, Hadfield and Main.²⁹ The conclusion is drawn that the heat evolved in the high carbon and high speed steels is far in excess of that due to the contraction alone. The rate of contraction in recently hardened steel is increased by heating and the magnitude is also affected.

²⁶C. Barus and V. Strouhal: Electrical and Magnetic Properties of Iron Carburets. U. S. Geol. Survey Bull. 14 (1885).

²⁷Iron Age (1890) 45, 585.

²⁸C. F. Brush: Spontaneous Generation of Heat in Recently Hardened Steel. Proc. Amer. Phil. Soc. (1915) 54, 154; Phys. Rev. N. S. (1917) 9, 228; Proc. Amer. Phil. Soc. (1917) 56, 353.

²⁹Brush, Hadfield and Main: Proc. Roy. Soc. London (1918) A95, 120.

Effect of Quenching Nickel-chromium Steels on Resistance to Impact.

The Midvale Steel Company has, for several years, known that certain nickel-chromium steels have low resistance to impact when cooled slowly from the tempering heat (about 600 degrees C.) but if quenched from the tempering heat the impact values are satisfactory. Philpot³⁰ gives many impact results on nickel-chromium steels showing the increased resistance produced by quenching from the tempering heat. This property in nickel-chromium steels is known as "blue brittleness." All steels of this class do not show the phenomenon of blue brittleness; it seems to be more pronounced in acid than in basic steel. The ratio between the impact values of the steel quenched from the tempering heat and that cooled slowly from the tempering heat may be considered as a rough measure of the susceptibility to blue brittleness. Some steels cooled slowly from the tempering heat show a higher impact resistance than when quenched from this temperature. Of one series of 20 tests, three showed higher impact values after slow cooling and 17 showed higher values after quenching. The ratio of impact resistance after quenching to that after slow cooling from the tempering heat varied from a little less than unity to 13. The general type of steel considered is typified by the following analysis: carbon, 0.40 per cent; nickel, 2.75 per cent; chromium, 0.85 per cent; manganese, 0.8 per cent; sulphur, 0.035 per cent; phosphorus, 0.025 per cent.

A steel susceptible to blue brittleness that has been made resistant to impact by quenching can have its impact value reduced by heating to temperatures between 750 degrees and 1,020 degrees F. (400 degrees and 555 degrees C.) regardless of the manner of cooling from these temperatures. A piece of steel originally having a low impact resistance produced by slow cooling from the tempering heat may have its impact value restored to normal by heating to about 1,100 degrees F. (593 degrees C. and quenching. Steel exhibiting the phenomenon of blue brittleness will, if tempered at consecutively higher temperatures beginning at 200 degrees F. show brittleness between 400 degrees and 1,000 degrees F., regardless of the manner of cooling from the tempering heat, but at 1,100 degrees F. the high resistance to impact can be restored.

Some interesting conclusions are drawn from results reported by Capt. H. F. Wood and R. S. Archer.³¹ The steels used contained: carbon, 0.3 to 0.4 per cent; manganese, 0.5 to 0.6 per cent; nickel, 2.75 to 3.15 per cent; chromium, 0.75 to 0.85 per cent; sulphur, less than 0.031 per cent; phosphorus, less than 0.035 per cent; silicon, less than 0.14 per cent. A certain steel was tested to make sure of its susceptibility to blue brittleness and was heated to 1,670 degrees F. (910 degrees C.) and air-cooled, then heated to 1,510 degrees F., held one hour and quenched in oil, and finally several samples were heated to 1,100 degrees to 1,125 de-

grees F., for one-half hour and cooled as here shown. The impact values are higher as the time of cooling to room temperature decreases.

Manner of Cooling	Izod Impact Values
Water quenched	50.0
Oil quenched	48.0
Air cooled	43.0
Furnace cooled	8.7

A piece of steel susceptible to blue brittleness that has been made resistant to impact by quenching from the tempering heat cannot be made brittle by heating quickly to a temperature of 950 degrees F. (510 degrees C.). This shows that appreciable time is required for the internal changes that cause the low impact values after the steel has cooled to take place at 950 degrees F. On the other hand, a very short exposure at 1,100 degrees F. (595 degrees C.) is sufficient to restore the impact resistance of a steel made brittle by previous slow cooling through the temperature range below 1,100 degrees F.

Wood and Archer describe experiments showing that a nickel-chromium steel susceptible to blue brittleness had a lower impact value when annealed and slowly cooled from 1,100 degrees F. than when the annealed steel is quenched from 1,100 degrees F. The brittleness developed is, therefore, inherent in the steel irrespective of the heat treatment previous to tempering.

Archer³² has shown, beyond question, that the impact fracture of certain of these steels after slow cooling from the tempering heat is intercrystalline. When the fracture is known to be intercrystalline the macroscopic appearance is described as "crystalline." On the other hand, it is certain that the fracture of the specimens showing a high impact values is transcrystalline; in such a sample the appearance of the fracture is fibrous. Wood and Archer describe the fractures of specimens having intermediate impact values partly crystalline and partly fibrous and have estimated roughly the percentage of each on certain fractures and have compared them to the impact values. These results are given in Table 6.

Table 6.

Treatment of Steel	Impact Test, Foot-pounds	Approximate Per Cent of Fractured Surface Appearing Crystalline
Annealed.....	4.0	100
Annealed.....	8.0	100
Annealed.....	8.0	100
Annealed.....	13.0	80
Annealed.....	16.0	70
Annealed.....	17.0	70
Annealed.....	33.5	60
Annealed.....	36.0	60
Annealed.....	42.5	20
Annealed.....	47.5	20
Hardened.....	26.0	50
Hardened.....	33.0	40
Hardened.....	48.5	0
Hardened.....	52.0	0

It appears that the cause of blue brittleness relates to changes tending to produce intercrystalline fracture and, consequently, the appearance of the fracture after impact test should be an indication of

³⁰H. T. Philpot: Some Experiments on Notched Bars. Jnl. Soc. Automot. Engrs. (1918) 3, 347.

³¹Report to Committee on Physical Changes in Iron and Steel below the Thermal Critical Range (Jan. 3, 1919)

³²R. S. Archer: Development of Grain Boundaries in Heat-treated Alloy Steels. Bull. (Jan., 1919) 51.

the impact resistance. It also appears that the grains are as deformable, or nearly so, in the samples showing low impact values as in those showing high values. The grain boundaries in the former become so weak that sufficient load to deform the grains themselves cannot be applied quickly without pulling them apart. The grains here referred to are, in outline, the old austenite grains although the heat treatment must have changed the interior from austenite to sorbite. One of the unusual characteristics of these steels is the persistence of the austenite grain boundaries after heat treatment.

The tensile properties of these steels showing low impact values are approximately the same as those showing high values. The blue-brittleness tendency is, therefore, not detected by the tensile tests. Precautions against blue brittleness advised by Wood and Archer are as follows: Temper above 1,020 degrees F. (550 degrees C.); quench from the tempering heat; avoid reheating any specimen to temperatures between 750 degrees and 1,020 degrees F. (440-550 degrees C.).

It is not certain that the steels having low impact values, provided the tensile properties are good, are unfit for use for aircraft-engine crankshafts or for similar purposes. It is considered safer, however, at the present time, to treat for a high impact value.

General Discussion.

The changes in the tensile properties of iron and steel with a rise in temperature are best explained by assuming a low-temperature allotrope in iron. Since all of the tensile properties change gradually with a rise in temperature rather than abruptly at a given temperature, the change from one allotrope to another would be considered to take place gradually. The point of maximum tensile strength need not be considered as the temperature at which the allotropic change on heating has been complete, but it would seem that the change takes place gradually between ordinary temperature and about 350 degrees C. The temperature of maximum strength might well correspond to the physical state of the metal in which both allotropes are present in about equal proportions. The difficulty of explaining the tensile properties of iron at elevated temperatures without assuming the existence of an additional low-temperature allotrope seems to the writer almost unsurmountable. The changes in tensile strength and elastic limit are opposite to those normally expected by increase in temperature. The magnitude of these changes of properties is such as to leave no doubt as to the existence of a maximum point in tensile strength and elastic limit at about 200 degree to 250 degrees C. Iron possesses considerable ductility throughout the entire temperature range within which these physical changes take place. The phenomenon cannot, therefore, be attributed to a change from a brittle to a ductile condition, or vice versa. Furthermore, the fracture of iron from room temperature to 500 degrees C. takes place through the grains rather than at the grain boundaries. This suggests that internal changes have taken place within the grains, other than those changes ordinarily produced by change in temperature alone. These grains

are composed of crystalline material. If a change within the grains of this crystalline material takes place between room temperature and 500 degrees F., why not call this an allotropic change? We have no other name for such a change at present. It should not be necessary for one allotrope to change to another at a specific temperature. The change might well take place at a particular temperature in the higher-temperature ranges, such as the A_3 point in pure iron, but at the low temperatures with high mechanical cohesion to resist allotropic change we might expect the transformation to be more sluggish. If there is a low-temperature allotrope in iron, the grains we examine under the microscope at room temperature are pseudomorphs of the grains formed originally when the iron was in another allotropic state. The temperature of the lower change is too low to permit a general recrystallization like that at A_3 .

It is assumed that allotropy can occur only in a crystalline phase and that amorphous metal exists between the grains of crystalline metal and is generated within the grains during plastic deformation. All of the results produced by cold deformation, as well as blue deformation reported above, accord nicely with the theory of the existence of a low-temperature allotrope in iron. We would expect the amorphous phase to change continuously with temperature and become weaker at 200 degrees to 300 degrees C. than at room temperature. In order that the elastic limit of iron may be higher at 200 degrees C. than at room temperature, the crystalline grains must have their elastic limit increased by increase in temperature. Since the tensile properties are functions of the quantity, arrangement, and properties of the amorphous and crystalline phases of iron, the greater amount of amorphous metal in severely cold-drawn iron wire produces less increase in strength at elevated temperatures than does the smaller amount of amorphous metal in annealed iron. Since the amorphous phase decreases in strength continuously with temperature, the Armco iron reduced by cold drawing 96 per cent of its original area was not stronger at any elevated temperature than at ordinary temperature. Since the crystalline phase of this same sample had increased in cohesion at the elevated temperatures, the tensile strength of even this severely deformed iron did not decrease at a regular rate with a rise in temperature; it decreased in strength but slightly up to 250 degrees to 300 degrees C., after which an additional increase in temperature produce a marked decrease in the tensile strength.

The failure to discover sharp changes in thermal and electrical conductivities of iron and steel with a rise in temperature is not necessarily evidence against the existence of a low-temperature allotrope in iron. The change from one allotrope to another throughout a temperature range of 300 degrees or more might mask any sharp change in these properties.

The explanation of some of the aging results described above is at the present time very problematical. It is certain that atomic rearrangements of considerable magnitude take place in iron and steel at room temperature. The mechanical cohesion resists

these atomic changes so that the time effect is very pronounced. For example, the spontaneous generation of heat in recently hardened steel which releases itself gradually during a period of five weeks or more is released quickly at an elevated temperature. Nearly all of the aging results, however, indicate an equilibrium condition of the metal reached after a long period at room temperature or a short period at 100 degrees C. Still higher temperatures may produce internal changes not reached in room-temperature aging.

The nature of these internal atomic changes may be either chemical or physical. In the elastic recovery of overstrained iron, for example, the internal changes would seem to be of the nature of the establishment of cohesion bonds between the atoms of the amorphous metal newly formed by the deformation. This gives rise to the speculation as to whether the establishment of cohesion bonds would generate heat in proportion to the latent heat of evaporation. Recently overstrained steel should be examined for spontaneous generation of heat and for spontaneous change of volume.

Having taken the stand that the tensile and deformational properties of iron and steel could not be explained without assuming the existence of a low-temperature allotrope, let us see if this assumption also assists in the explanation of some of the other observations noted.

The formation of folds³³ would indicate a volume change from one allotrope to another and also would indicate that the rate of change from one allotrope to another is so slow that quenching prevents the transformation from taking place during cooling but allows it to take place at the temperature of the quenching bath. The fact that a small piece will not develop these folds would indicate that the effect is cumulative in a large piece and may not reach sufficient magnitude in a piece of 1 cm square to cause the initiation of the folding.

It is reported that quenching alone from blue heat affects the properties of steel. This can be explained readily by assuming a low temperature allotrope.

The spontaneous generation of heat, the contraction, and the decrease in electrical resistivity at ordinary and slightly elevated temperatures in hardened and untempered high-carbon steels are probably results of the same internal changes. These changes are produced in a few minutes in hardened tool steels by tempering between 175 degrees and 300 degrees C. If we did not suspect the existence of a low-temperature allotrope, we would attribute these changes to the normal tendency of martensite to change toward troostite; but because of the strong evidence of the actual existence of such an allotrope, we are tempted to attribute at least part of the changes to it. The greatly increased hardness due to the carbon and quenching might retard the transformation of the low-temperature allotrope to such an extent that the change is incomplete with rapid cooling through this range. The completion of the transformation would

take place slowly at room temperature and more rapidly at 100 degrees C.

Blue brittleness in nickel-chromium steels seems to involve relative changes in properties of the grain-boundary material and the grain material. This relative change might be caused by differential volume changes in the two materials, due to different rates of cooling from the various temperatures; or there may be an actual precipitation on cooling and absorption on heating of excess material at the grain boundaries, the rapid cooling from the higher tempering heats preventing the precipitation. The thermal point below A_1 reported by Dr. Mathews would indicate some condition like the latter. This is complicated by the presence of nickel and chromium, especially the former, which has such peculiar effects on steel when present in large amounts.

A rather comprehensive investigation of blue brittleness in various steels is in progress by some members of the committee, namely, Miller, Mathews, Wood, Nelson, and Foley.

In the interpretation of all these changes in properties of iron and steel at low temperatures, we have to consider the question of internal strain. The modern diagnosis for unusual metal ills is "internal strain." That these strains exist is not doubted; but we call ailments of all kinds and magnitudes and due to different causes, internal strains. We may have internal strains between like atoms, between atoms of two or more elements, between groups of like atoms or unlike atoms; these may be either chemical or physical strains. We have also regional internal strains of as many varieties as we have external stresses. To simply say that a metal is afflicted with internal strains is the same as saying that a patient is sick without consideration of the cause or remedy.

Take, for example, the spontaneous contraction in recently hardened steel reported by Brush; did the diameter of the small rod that he used contract in proportion to the contraction in length? Let us assume that it did. If we consider that the contraction was due to internal strains, we could bring the rod back to its original length by applying simple tension; but, in accordance with Poisson's ratio, this would actually decrease the diameter. The only way we could restore the shape to the original one would be by applying negative hydrostatic pressure, and it is obvious that this would not restore the atoms to their original positions. Such internal strains would be very complex. The rod used by Brush was so small that it must have hardened to its axis. When a large block of high-carbon steel, like a forging die, is quenched, however, only the outside shell is changed to martensite, and several degrees of hardness obtain between the shell and the interior parts. We can imagine these layers of different hardness having different magnitudes of spontaneous contraction; rest at room temperature might thus cause such an increase in internal strains that the shell would rupture or crack. This spontaneous cracking of large die blocks is common and the remedy is to allow as little time as possible between the quench and the draw and

³³B. Bogitch: Op. cit.

in some cases, to insure against such cracks, the quenching water should be hot.

Owing to the uncertainty as to the nature of martensite, troosite, etc., and the possibilities for both physical and chemical changes, the explanations of the observations discussed in this paper must await additional data. The following points would make excellent subjects for research at colleges and universities and research laboratories in the steel industry:

1. Is there a difference in volume between samples of steel quenched from 200 degrees to 400 degrees C. and slowly cooled from this range? Is there a change in physical properties?
2. Does recently overstrained iron and steel generate heat at room temperature? Is there a volume change corresponding to the recovery of elasticity?
3. Is the spontaneous contraction in recently hardened steel uniform or directional?
4. How can we establish the existence or non-existence of the low-temperature allotrope in iron beyond reasonable doubt?
5. What are the deformational characteristics of low-carbon martensite at ordinary temperature and at blue heat? Also the tensile properties?

No doubt much information is extant that would help to answer some of these questions and if so it is hoped that it will be offered in discussion.

Practical Value of Work in This Field.

The question of hot straightening of warped forgings is important; and if straightening bent forgings at a blue heat is detrimental, this fact should be known. It is also conceivable that the variations in properties of iron and steel produced by blue-heat deformation might be taken advantage of for useful purposes in the future.

The old-time practice of tempering high-carbon steel at temperatures so low that no appreciable change in hardness occurs is seen, from the above descriptions, to have good scientific foundations. The slow changes in volume at room temperature may even produce cracks in high-carbon steels quenched but not tem-

pered. This is so pronounced in certain large pieces that the tempering must follow the quenching almost immediately, to avoid the formation of so-called quenching cracks. In certain steels, quenching in hot water and oil are resorted to because cold-water quenching might produce these cracks before the steel could be removed from the bath or even during cooling.

Rosenhain and Archbutt³⁴ report the formation of intercrystalline cracks that, eventually, produce failure in mild-steel boiler plates. These boiler plates are used at a relatively high temperature and it is the belief of the authors that the long-sustained load at the high temperatures causes the amorphous cement at the grain boundaries to gradually flow and eventually break without deformation of the grains. This involves the study of the action of steel under sustained loads at elevated temperature, which subject is now being investigated by H. J. French at the Bureau of Standards. Epps and Jones state that the elastic limit of wrought iron at 600 degrees F. (315 degrees C.) is only half that at room temperature; hence in designing tubes, valves, pipe lines, etc., for carrying superheated steam, a safety factor of 10 should be used on the basis of the tensile strength at room temperature. This would represent a factor of safety of 3 on the elastic limit at 600 degrees F.

Quenching nickel-chromium steels from the tempering heat is resorted to in many cases to increase the resistance to impact. While there may be criticisms to the effect that the high impact values so produced are unnecessary, there seems to be no contention that such steel is inferior to that which has been slowly cooled.

In conclusion, it may be stated that information on all of the subjects treated in this paper will help, either directly or indirectly, in the production, treatment, and control of iron and steel with properties more suitable to the uses of mankind.

³⁴Rosenhain and Archbutt: Proc. Roy. Soc. London (1919) A96, 55.

Electric Rolling Mill Drive Equipment

How Layout of Mill and Method of Rolling the Steel Affects the Load Cycle—Motor Capacity, Size of Flywheel and Type of Control.

By J. D. WRIGHT.

IT is the purpose of this paper to discuss the general subject of electric mill drives with particular reference to some of the factors which influence the selection of the electrical equipment for driving the main rolls of various types of mills.

It is proposed to illustrate how the layout of the mill and method of rolling the steel affects the load cycle from which the motor capacity, size of flywheel, type of control, etc., are determined.

Paper read before Philadelphia section of the Association of Iron and Steel Electrical Engineers, January 3, 1920.

One of the simplest of the large motor applications is to a continuous mill such as a six-stand continuous sheet bar or billet mill built by the Morgan Construction Company, a layout of which is shown in Fig. 1. A mill of this type receives its steel in the form of a bloom having a section around 6 inches by 7 inches direct from a blooming mill. The size of the bloom of course will vary with the size, number of stands and product of the continuous mill, but a 6-inch by 7-inch section is typical.

Since the stands of the continuous mill are spaced

with only a few feet between centers the load builds up to the maximum in a series of steps as shown in Fig. 2, the successive step representing the entrance

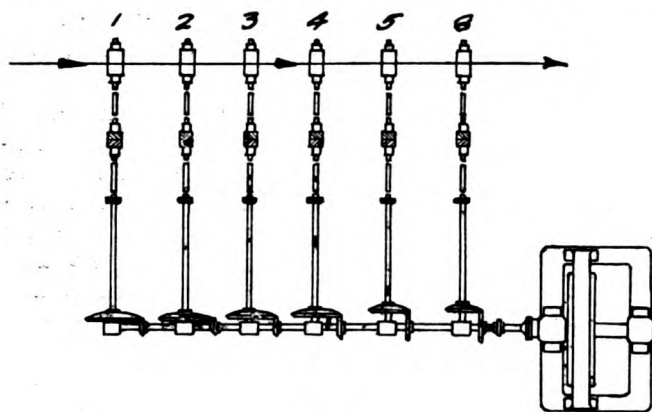


Fig. 1.

of the steel into successive stands. Since the bloom is fairly long the steel remains in all stands for a considerable number of seconds. The reason for stating that a continuous mill drive represents one of the simplest of the large motor applications will be evident from the load curve of Fig. 2. The load comes on in several easy steps and remains on for some time. The motor is not subjected to shocks caused by sudden high peak loads. Therefore, no flywheel is required. Since no flywheel is used the motor has only the friction load of the mill when starting under normal conditions. It accelerates to maximum speed and continues to run at that speed with or without load. On account of quick and easy starting conditions the motor may profitably be shut down when waiting for steel from the bloomer.

On account of the accuracy with which the load may be calculated the motor capacity may readily be determined.

In the great majority of cases the motor is direct connected to the lay shaft as shown in Fig. 1 although

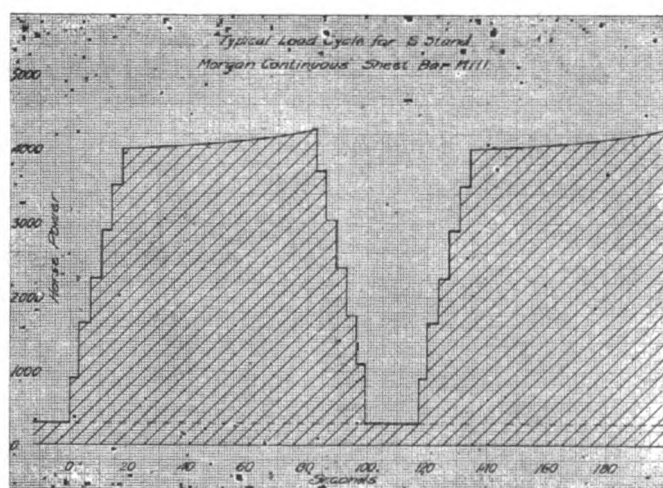


Fig. 2.

the nature of the load is such that it probably represents the easiest gear drive of any kind of rolling mill load. However, since the speed of the lay shaft is

usually around 82 as a minimum, direct connected motors are a perfectly practical design for either 25 or 60 cycle circuits, and are therefore to be preferred. A slip ring type induction motor is of course always used.

The power consumption in kilowatt hours per ton for mills of this type of course depends on the size of bloom and finished product, and on the tonnage rolled. Average figures on a combined four-stand 21-inch and six-stand 18-inch continuous mill show approximately 23 kwh per ton, including main roll and auxiliaries. Average figures on a four-stand 21-inch mill and six-stand 18-inch mill each driven by a separate motor show a total of approximately 22 kwh per ton, main motors only. Such figures as these are, however, of little value unless the size of the bloom and finished product are specified.

To date a total motor capacity of approximately 80,000 hp has been applied in this country to this important type of rolling mill.

Fig. 3 shows the mill layout and calculated load curve for a three-stand combination rail and struc-

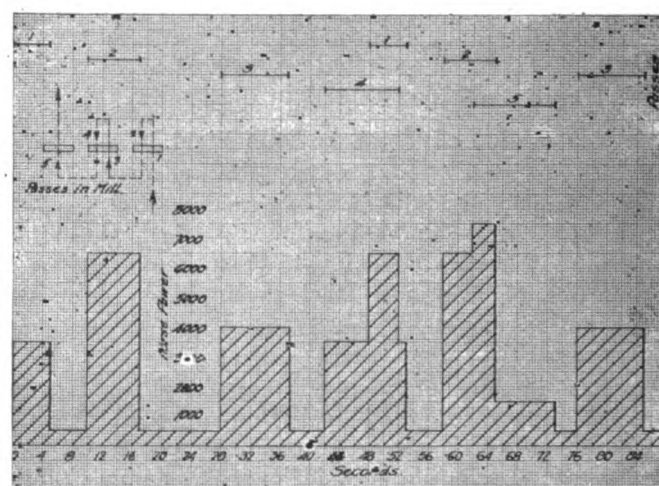


Fig. 3.

tural mill which is served by two tilting tables on the entering side of the mill. When rolling 85-pound rails, for example, five finishing passes are made, two in the first stand, two in the second and the final pass in the third stand. The right hand traveling table receives the bloom from the roughing mill and after passes 1 and 2 have been made in the first stand, transfers the steel to the second stand. As soon as the third pass has been finished this table moves back to its original position to receive the second bloom and at the same time the left hand table takes its position in front of the second stand to receive pass four and transfer the material to the third stand for pass five. The time for each pass and the interval between passes are represented by the diagram above the load cycle. Assuming that a bloom is rolled every 48 seconds there would be overlapping of passes 1 and 4, and 2 and 5, as indicated. It is evident that pass 1 cannot occur simultaneously with pass 2 or 3, but can with 4 or 5. In the same way pass 2 can occur with only 4 or 5 and pass 3 with pass 5. With the traveling tables working together properly and without de-

lay in entering the steel, overlapping would probably occur as shown in Fig. 3. It will be seen from this diagram that the maximum load is 7,500 hp and this peak load lasts for three seconds. Assuming, however, that a delay caused by difficulty in entering the steel for pass 4 occurs we might have overlapping of passes as indicated by Fig. 4. Here the load conditions are less favorable, the maximum peak being 9,500 hp caused by overlapping of passes 2 and 4, and this load lasts for four seconds. While this would not be a normal condition of rolling the motor and flywheel would have to be designed to take care of this condition.

The normal capacity of the motor should be calculated from the normal rolling schedule which in this particular case would be that represented by Fig. 3. The average load from the 42-second point to the 90-second point (this portion under normal conditions being continued by repetition) is 3,200 hp, whereas the root mean square or heating capacity of the load is 4,050 hp. Theoretically the stored energy in the flywheel should be such that the motor would carry only the average load, the flywheel giving up its energy when the rolling load exceeded the average and having

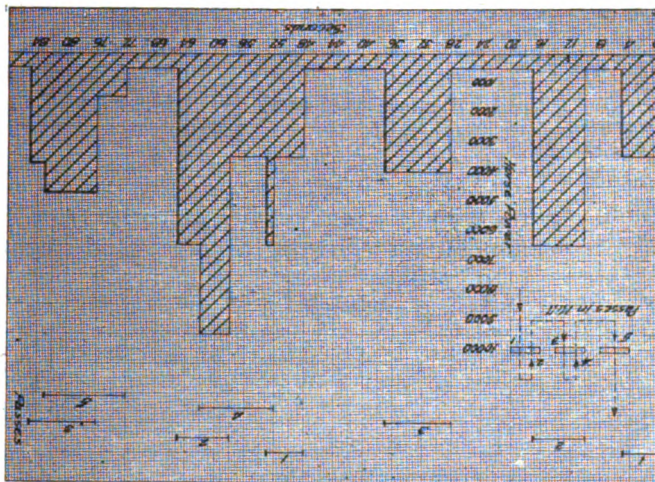


Fig. 4.

energy stored in it by the motor when the rolling load was below the average. However, in actual practice this condition is rarely if ever attained. In the great majority of cases to completely equalize the load would require an excessively heavy flywheel, or too great a drop in speed. Furthermore, there is rarely, if ever, anything to be gained by preventing the motor carrying overloads within its torque and heating capacity. There have been cases where, on account of limitations in generating capacity, it has been found necessary to limit the input to the motor to slightly above normal. Referring again to Fig. 3 and assuming that the flywheel was up to maximum speed at the 42-second point it is found that to prevent the load on the motor exceeding the average of 3,200 hp the flywheel would have to deliver a maximum of approximately 27,900 hp sec. To do this with a 15 per cent speed drop would require a wheel with a stored energy of approximately 100,000 hp sec or 55,000,000 foot pounds. At 90 rpm a wheel 22 feet in diameter, hav-

ing this amount of energy would weigh approximately 490,000 pounds or 245 tons, which is of course ridiculous. As a matter of fact about all that any fly-

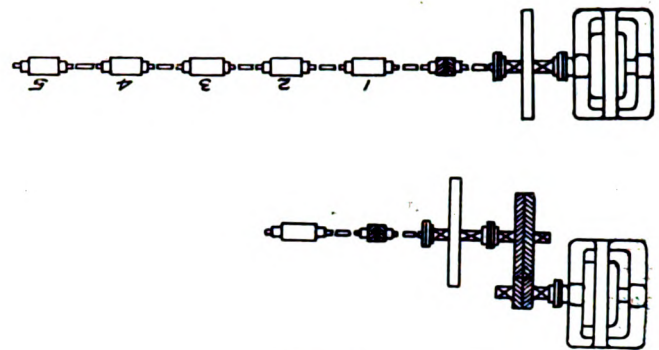


Fig. 5.

wheel of normal design could do on a load cycle such as represented in Fig. 3 would be to ease the load on and off the motor. The loads are of such duration that before the pass is through the motor would be carrying the entire load.

Probably the largest number of motor applications to rolling mills have been made to so-called merchant mills. A most excellent bulletin published by the

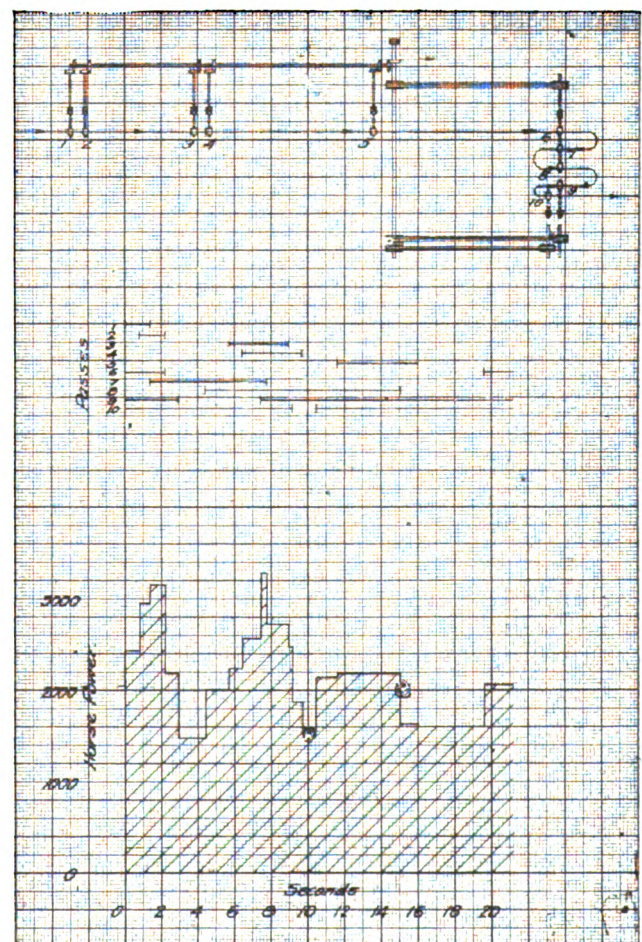


Fig. 6.

United Engineering & Foundry Co. describes a merchant mill in the broad sense "as any mill which produces a general line of merchant bars, that is rounds,

squares, flats and small shapes." A simple merchant mill consists of several stands of rolls arranged in a straight line similar to the layout shown at the bottom of Fig. 5. The material is fed to the mill by hand, the billet being roughed in the No. 1 stand next to the pinions and then passes successively through the remaining stands and finished in the last stand which is usually called the finisher. Under some conditions of rolling the bar is allowed to run out onto the floor and the last end entered into the next pass. Frequently, however, after the roughing passes have been made the material is looped from stand to stand so that the load on the motor is a combination of several passes. Overlapping of the roughing passes with the later passes may also occur if a sufficiently large crew is employed. A flywheel will usually be found necessary to help out on the short high peaks caused by the roughing passes.

Instead of this simple type of mill there is now in common use what is known as the Belgian mill which consists of a single roughing stand in combination with an ordinary guide mill as shown by Fig. 5. The use of this separate roughing stand gives increased tonnage by allowing the finishing rolls to be run at a higher speed than would be possible where the roughing and finishing stands must run at the same speed. The roughing mill is also usually of larger diameter than the finishing mill. Fig. 5 shows the layout of a United Engineering & Foundry installation of a 14-inch roughing and 10-inch finishing mill at the plant of the Buffalo Bolt Company. It will be found that the use of a separate motor driven rougher frequently eliminates the necessity of a flywheel on the finishing stands. The length of bar produced may cause loads of such duration that a flywheel would be of no value in reducing the peak load on the motor. As in the case of the combination rail and structural mill previously discussed in order to calculate the load which the motor will be called upon to carry it is necessary to know the layout of the mill and method of rolling the material so that the loads due to overlapping passes may be determined.

In order to still further increase the tonnage of merchant mills the hand fed roughing mill of the Belgian train has in many cases been eliminated. Fig. 6 shows the layout of a semi-continuous type of mill in which the billet is fed directly from the heating furnace into the first roughing stand. It is fed by hand only into stands 7, 8, 9 and 10. This figure also shows the load cycle for a particular section with overlapping of passes caused by entering billets into the first stand at 21 seconds intervals.

In closing it might be well to state that in order to calculate the proper size of motor required to roll any given product it is necessary to have the following information:

1. Size and type of mill.

2. Mechanical data.

Description of mill

Reversing or non-reversing

Number and arrangement of stands (show sketch)

Working diameter of rolls

Rpm of roll

Is mill provided with flywheel? If so give weight, diameter, rpm and stored energy in foot pounds or hp seconds at maximum speed.

Method of Drive:

How will motor be connected to mill:

Direct connected, geared, rope, belt, chain.

Type of coupling: solid, flexible.

3. Operating Data:

Maximum tonnage per hour and normal tonnage per 6 hours or per shift.

Number of shifts and total time operation per day.

Initial weight and dimensions of steel

Final dimensions of steel

Character of steel (carbon content)

Number of passes

Section of steel after each pass

Method of handling steel between passes

Maximum number of passes filled at one time
Does steel come direct from another mill without re-heating? If so, give initial weight and dimensions, number of passes and time in first mill.

4. Motor Data:

Alternating current or direct current:

If ac, state voltage, frequency and number of phases.

If dc, state voltage.

Is motor to be provided with flywheel? If so, give weight, diameter and stored energy in foot pounds or hp seconds at maximum speed.

Temperature guarantees.

Speed requirements:

Speed in rpm

Constant, adjustable or variable

If adjustable speed, how many intermediate speed points are desired between minimum and maximum?

How frequently will speed be adjusted?

How rapidly must a change in speed be effected?

If adjustable speed is required, does hp remain constant or vary with the speed? If so, how?

Frequency of starting and stopping.

Must control be arranged so that motor can be reversed in case of emergency?

Will jogging for the adjustment of the mill be required?

If so, how frequently?

Should motor be provided with a thrust collar or breakable end thrust?

Present Status of Nickel-Chromium Alloys

**Early Development—Properties of Alloys Available for Resistance
Purposes—Requisites of Good Material for Heating Elements—
Different Uses to Which Nickel-Chromium Is Adapted.**

By W. A. GATWARD.

THE peculiar properties of nickel-chromium alloys, which make them especially suitable as resistance units for heating devices, were discovered by A. L. Marsh in 1905. The early stages of research consisted of several hundred experiments on different combinations of nickel and chromium, as well as combinations including these two metals and one or more additional metals. Conclusions arrived at after years of work are that the desirable properties are due to the peculiar effect of chromium. The discovery that the alloys of nickel and chromium had desirable properties, was not the end of the problem; it was necessary to develop alloys that had all the good properties and which at the same time could be cast, rolled, and drawn into suitable form. There is no doubt, even now, that the manufacture of nickel-chromium is one of the most difficult problems in metallurgy. It was even more so at first, due to lack of experience. Both nickel and chromium melt at high temperatures and nickel is a solvent for carbon. Furthermore, chromium at the melting point is very easily oxidized. Hence the alloy in the early days was subject to widely varying percentages of carbon which greatly affected its rolling, and the castings were very much subject to the effects of included and dissolved oxides. Proper methods of deoxidation had to be developed. There were many months when it was impossible to reduce any metal to wire form. Bars were very small until recent years and the smaller the bars the more subject they were to varying properties. Another difficulty was the variation in the composition of the raw materials. There is no difficulty now in obtaining plenty of nickel and chromium but the fact of the matter is that the nickel-chromium alloy has been partly responsible for the development of the pure nickel and pure chromium supply. During the development of the alloys the raw materials were not so dependable.

With all respect to science, it is true that the nickel-chromium industry since the very beginning has been free from hair-splitting scientific calculations. This is inherently true of research in alloys, and the nickel-chromium industry has shown it very clearly. This does not mean that brains are not necessary; neither does it mean that the work is not done in a scientific way—nothing is farther from the truth—but there is not a single step in the development or in the process of manufacture that was not worked out entirely by experiment, and at no time has it been possible even to guess what would be the properties of untried alloys or what would be the effect of any of the many variations in the processes of production.

Paper read before Engineers' Society of Western Pennsylvania.

The problem of the producers has been to observe past results, to determine what things to try and then to make the experiments and select the good from the bad. The slightest change in the process is apt to affect results at some later stage, hence there must be careful control at all times.

Present Status of the Industry.

The present standing of the nickel-chromium industry is probably higher than is generally known. Since 1906, about 2,000 tons of nickel-chromium have been used in the manufacture of heating devices. In considering the importance of the alloy industry one must include the allied industries and these include the production of the raw materials—nickel and chromium—and the manufacture of various sorts of heating devices.

The fact that nickel-chromium is the only commercial substitute for platinum as a heat resisting material, should speak for itself. The many devices in use today, both in domestic and industrial work, are only a few stages removed from luxuries. Three factors were active in changing these devices from luxuries to necessities. They were as follows: (1) cost of electrical current, (2) development of nickel-chromium heating elements, (3) large-scale production of the devices. The first item, cost of current, was a stumbling block for a long time but central stations are now seeing the advantages of the "off-peak" load and are giving rates which are entirely satisfactory. The second item is the real solution to the problem as the first and third items were inevitable once the second item had been taken care of. A device is or is not a luxury depending on whether or not it is durable. In other words, a toast stove which cost \$5 and lasts only a month is a luxury, while a toast stove which costs \$5 and lasts five years is not a luxury.

It would be a broad statement to say that had Mr. Marsh not developed his alloy it would not have been developed eventually by some one else, but it is a fact that this alloy is indirectly responsible for the present standing of the nickel and pure chromium business and for the entire field of domestic and industrial heating.

The third point mentioned above—large-scale production—has been important in making possible the general use of domestic heating devices. One can purchase for very reasonable prices devices which have real quality, both in material and workmanship, a condition due entirely to large-scale production and merchandising.

Properties of Alloys Available for Resistance Purposes.

Before going into the subject of available materials

and their properties I would like to clear up an idea which is very prevalent. The term "nickel-chromium alloys," as generally used, includes alloys of nickel and chromium and also alloys of nickel-chromium with manganese, aluminum, iron, or silicon in varying percentages. An alloy used considerably and known as "Nichrome" is one of these alloys and it is generally thought that it is the only alloy available and that it is made by the Hoskins Manufacturing Company, of Detroit, as well as by the Driver-Harris Company, of Harrison, N. J. Such is not the case. "Nichrome" is an alloy of 65 per cent Ni., 24 per cent Fe. and 11 per cent Cr., and is manufactured by the Driver-Harris Company under the name of "Nichrome," while the same alloy is made by the Hoskins Manufacturing Company, under the trade name of "Chromel C."

The following table gives a list of the available alloys of nickel-chromium and modifications of the pure alloy. Column 1 gives the trade name, column 2 the name of the manufacturer, column 3 the composition, column 4 the ohms per circular mil foot, column 5 the published temperature coefficient, and column 6 the working range. The various items are tabulated for comparison:

Name	Maker	Published composition	Ohms per circular mil foot	Average coefficient per degree F.	Temperature range degrees F.
"Chromel A"	Hoskins Mfg. Co.	80% Ni., 20% Cr.	620	0.00006	2,000
"Chromel B"	Hoskins Mfg. Co.	85% Ni., 15% Cr.	535	0.00006	2,000
"Rayo"	Electrical Alloy Co.	85% Ni., 15% Cr.	575	0.0001	2,000
"Kromore"	Driver-Harris Co.	85% Ni., 15% Cr.	570	0.0001	2,000
"Chromel C"	Hoskins Mfg. Co.	65% Ni., 24% Fe., 11% Cr.	650	0.0001	1,000
"Nichrome"	Driver-Harris Co.	65% Ni., 24% Fe., 11% Cr.	600	0.00024	1,000
"Calido"	Electrical Alloy Co.	65% Ni., 24% Fe., 11% Cr.	600	0.0002	1,000
Copper			9.4	0.00238	212
Aluminum			17.3	0.00235	212
Iron			58.0	0.00347	212
Nickel			74.0	0.0034	1,800

A study of this table will show the reader that he has a rather wide range of physical properties from which to choose. All are sufficiently high in resistance to be classed as heating-element material. The only limit for resistance is that the material shall have sufficient resistance so that a wire, which can be placed in a unit of convenient size, shall at the same time be large enough in cross-section so that the current it carries will not heat it beyond its safe temperature.

Both specific resistance and temperature coefficient are satisfactory. The important feature is resistance to oxidation at a high temperature. Results of years of experience and hundreds of life tests have proved that the alloy "Chromel A" is the most desirable alloy available. This durability is a hard thing to define and to specify but it can at least be said that at 1,000 degrees C. this alloy has a life from 10 to 20 per cent greater than for any other straight nickel-chromium alloy. At 800 degrees C. they are all very durable but as the temperature increases the life is shortened. The "A" grade at 1,000 degrees C. is about twice as durable as the "C" grade for the same temperature. This factor of safety in "Chromel A" is very important

in resisting the formation of hot spots.

Requisites of Good Materials for Heating Elements.

The requisites of a good material for heating elements are many. Some are purely physical and some rest on economic principles. The principal points are as follows: (1) High specific resistance, (2) Low temperature coefficient, (3) Reliable temperature coefficient, (4) Reliable composition, (5) Accurate size, (6) Reasonably long sections, (7) Proper spooling, (8) Durability at a temperature considerably above its operating temperature, (9) High conductivity of heat—a requirement which can not be perfectly attained, (10) Clean surface, (11) Smooth surface, (12) Uniform annealing, (13) Freedom from defects.

1. The specific resistance must be high. Any wire can be used, to a certain extent, as a heating unit. The trouble is that in using low resistance wire one must use either a small section or a considerable length. The device usually is such that there is a limit to the length that can be used and of course the weight will also be greater for low resistance material. If a small section is used the length will be slight but the radiating surface will be small and in order for the

wire to radiate the heat developed it will operate at an excessive temperature. If the specific resistance is high, a larger wire may be used and the wire will operate at a lower temperature.

2. The temperature coefficient of the material should be low. It is desirable that the current that flows when a device is first connected shall not be much greater than when the unit is heated but this is not the most important feature. The development of hot spots (which will be discussed later) is very much affected by the temperature coefficient. Another effect of high temperature coefficient is as follows. Imagine a heating unit wound around a muffle as generally used in electric laboratory furnaces. The heating unit is a continuous piece of wire. Suppose that the furnace is operating at 1,800 degrees F. and we place on the floor a fire-clay brick. The fire-clay brick immediately banks up the flow of heat and the temperature of the wire under the brick rises. This is not a theory but a fact and the rise is very serious. As the wire under the brick gets hotter its resistance increases. Since the current is the same in all parts of the heating coil, the heat developed I^2R , will be

greater on the floor than on the sides and top. Of course this phenomenon is cumulative and is the actual cause of many burn-outs in industrial devices. The higher the temperature coefficient the more serious this will be.

3. The reliability of the temperature coefficient is very important to the manufacturer. In designing a device the wattage is determined first. Then the future devices that are built are supplied with a measured amount of "cold resistance." The temperature coefficient must be uniform or the devices will consume varying wattages at full load.

4. The durability of the heating unit depends absolutely on the composition and of course this must be carefully controlled. It has been found that the durability at high temperatures is reduced both by decrease of chromium and by the presence of iron.

5. The size must be very accurate. This is not so important as the resistance per foot but since one determines the other it is desirable for the manufacturer of the wire to draw very carefully to size.

6. The length of the pieces of wire is important because of endage losses.

7. The spooling should be carefully done in order that the wire may be removed from the spool without tangling.

8. The limit of life of a normal heating unit is either oxidation to a point at which the heat developed is not sufficient, or the development of a hot spot with a subsequent burn-out. The later point will be discussed in a separate paragraph. Any device is subject to abuse and the greater the factor of safety the more satisfactory will be the device. The unit should not only be durable at the temperature at which it is supposed to operate but it should be durable at a temperature very much above that at which it is rated.

9. It is desirable, but apparently impossible, to obtain a heating unit of high specific resistance and at the same time of high heat conductivity. In all cases, low electric conductivity and low thermal conductivity go hand in hand. The thermal conductivity of nickel-chromium alloys is about one-fourth that of copper. It is necessary that the heat developed at the very center of a wire be carried to the surface and there radiated. Low thermal conductivity, therefore, means that a wire is a little hotter at the center.

10. It is desirable that the wire have a perfectly clean surface so that it may be soldered and brazed easily. Not all nickel-chromium wire can be produced perfectly bright but the Hoskins Manufacturing Company is now producing most sizes with a perfectly clean surface.

11. Units are usually wound by hand and the wire should have a smooth surface.

12. The wire must be uniformly annealed so that when coiled it will stretch evenly.

13. The wire must be free from defects. A slight decrease in effective cross-section tends to cause the development of hot spots and subsequent burn-outs.

Peculiar Properties of Nickel-Chromium Alloys.

Certain peculiar properties of nickel-chromium

are responsible for its success. One of these is the tendency toward self protection against oxidation by the formation of a close clinging scale. Oxidation takes place immediately when the wire is heated but the scale that forms protects the wire from further oxidation and this scale clings to the surface very closely even on repeated heating and cooling. This property of course varies with the temperature; it is particularly noticeable in "Chromel A" at 1,000 degrees C., is not so characteristic of "Chromel C" at 1,000 degrees C., but is true of "Chromel C" at 800 degrees C. If coils of "Chromel A" and "Chromel C" are heated for some hours at 1,000 degrees C., a little pile of brown powder will be found to have fallen from the "C" coil while the scale will be found to have clung close to the "A" sample. The formation of this refractory oxid may be further illustrated. A wire can be supported and heated by a current to a white heat and the wire will last for some seconds at a temperature considerably above the actual melting point of the alloy. When the wire finally burns out it will be found to consist of a tube, sometimes wrinkled. The core has melted and run while the oxid remains. During the time the current was flowing the wire consisted of this oxid tube containing a thread of molten metal.

Another peculiarity is the resistance to the formation of hot spots. The tendency to their formation is normal for any wire. The peculiar properties which resist the formation of the hot spots in "Chromel" are the low temperature coefficient and resistance of oxidation on the surface of the hot spot. Assume for a moment a wire having a high temperature coefficient and one which easily oxidizes at a red heat. Assume also that it is carrying a current. There is very apt to be one little spot which is slightly higher in resistance than all other points along the wire. This spot soon reaches a slightly higher temperature. Now, since we assumed a high temperature coefficient, we will find that the hot spot develops a little higher resistance. This, in turn, causes a greater development of heat and the cumulative result is a very hot spot which either oxidizes away or actually melts. To counteract these effects we must have a wire with a low temperature coefficient, which does not oxidize readily at high temperatures and which has a high melting point.

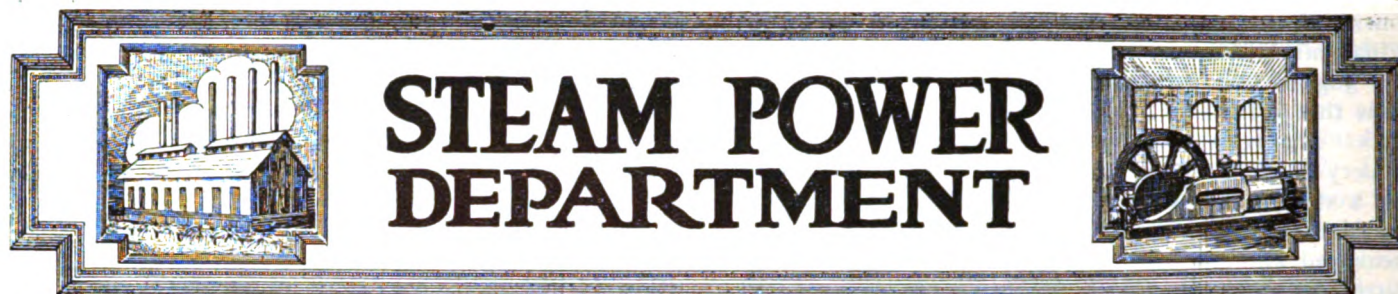
Another property of "Chromel" is its very dependable thermo-electric character. The millivoltage can be controlled perfectly and, since the alloy is highly resistant to oxidation, it is used with marked success as a thermo-couple element.

Uses to Which Nickel-Chromium Is Adapted.

The uses to which nickel-chromium can be put are varied. Tabulated they are as follows:

- Rheostats (low temperature).
- Ovens (300 to 400 degrees F.).
- Irons (700 to 900 degrees F.).
- Cook stoves and grills (red heat).
- Laboratory devices (1,800 to 2,000 degrees F.).
- Heat treating furnaces (1,600 degrees F.).

(Continued on page 263)



Economy of Stokers and Turbo Generators

Discussing the Generation of Electric Power and Defining the Necessary Equipment for Power Plant With Reference to Stokers, Types of Generators and Rotary Converters.

THE extended use of stokers is due to the fact that they save money by accomplishing the following results: The cost of labor is reduced; fuel is saved; smokeless combustion is secured, and boiler capacity is increased. The value of labor-saving machinery is not measurable in the saving of wages alone, because its real value lies in the fact that it attracts a higher class of men to a line of work in which they would not, otherwise, be willing to engage.

It requires a man of intelligence to fire a boiler properly, and it is poor policy to limit his activities to the small amount of fuel that he can fire by hand. He should be supplied with such mechanical appliances as will enable him to secure the best possible results.

A mechanical stoker is not a substitute for intelligence, and good judgment. It is only a substitute for manual skill, muscular strength and physical endurance. It performs its duties regularly and above all, it is reliable. Once placed in operation, it continues its work unceasingly and without variation.

The saving in cost of labor in any particular plant is so dependent on local conditions that no figures applicable to all plants can be given.

With a good mechanical stoker, however, the fuel is

supplied at a uniform rate, resulting in uniform distillation of the volatile gases. These gases are thoroughly mixed with the proper amount of air at a sufficiently high temperature to secure perfect combustion.

Another distinct fuel saving advantage gained in using stokers is that the ash may be removed without disturbing the fuel bed. A general survey of the stoker field indi-

cates that during the past year the country at large has spent about \$10,000,000 for mechanical stoker equipment. There are, of course, a large number of manufacturers who have shared in furnishing this equipment. In order that the best interests of the purchaser and the industry, as a whole be at all times kept in mind, a Stoker Manufacturers Association has been formed. The fundamental purpose of this association is to formulate certain lines of procedure

that will furnish everyone with an equal chance in competition and make it possible for the purchaser to judge by a common standard the merits of the different types of apparatus offered. It is a well established fact in other lines that associations of this kind have been one of the most important forces in developing their industry along broad gauge and worthwhile lines. The Stoker Manufacturers Association has such a purpose. Through its pub-

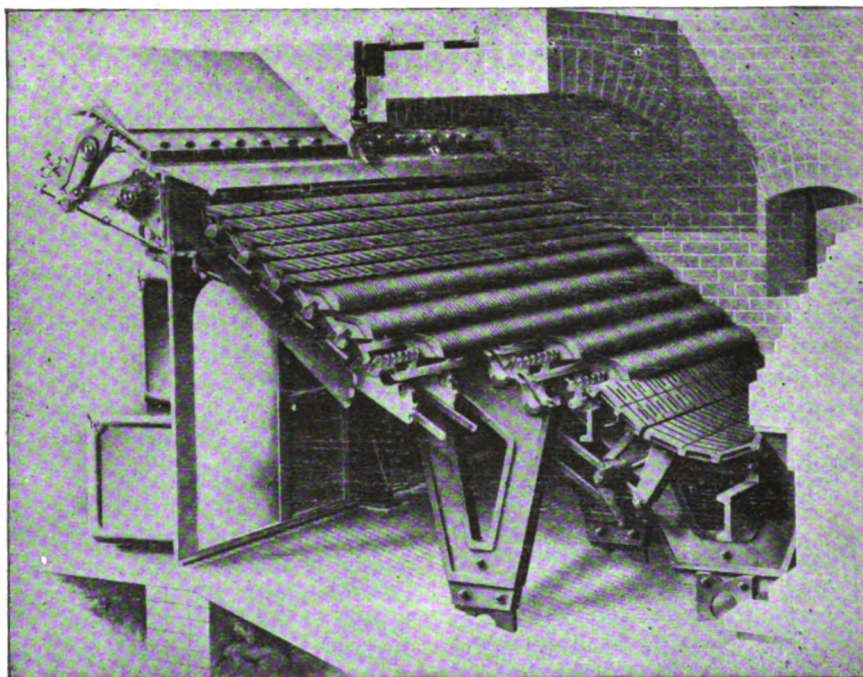


Fig. 1—Sectional view, in perspective of a mechanical stoker.

licity committee it hopes to so disseminate a knowledge of the advantages of mechanical firing that the owner of every power plant, including the small as well as the large ones, may know its value to him.

This association through its Engineering Committee is constantly on the watch for ideas that will improve any of the different types of mechanical stokers and so be in a position to make reports on praiseworthy engineering development both in this country and abroad.

During the 23 years that have elapsed since the steam turbine was introduced into America, there has been a complete revolution in the design of electric power plants. The superior economy of the turbine generator unit, not only in steam consumption, but in first cost, attendance

and in maintenance as well, and the reduction it has effected in general plant investment, in real estate, buildings, foundations, has eliminated practically the large slow-moving reciprocating engine-driven sets from the serious consideration of the modern power plant engineer and designer.

The elementary principles of the steam turbine are now generally known, and there is so much literature on the subject available, that any extended theoretical discussion would be superfluous. Broadly speaking, steam turbines are of two general classes; those employing the reaction principle, and those employing the impulse principle.

In the reaction turbine, approximately one-half of the expansion in any one stage takes place by stationary blades, imparting to the steam a velocity substantially equal to that of the moving blades, so that it enters them without impact. The remainder of the expansion takes place in the moving blades, the spaces between them gradually grow smaller from the inlet to the exit side of the turbine forming a ring of moving nozzles. The velocity imparted to the steam by reason of the expansion

occurring in the moving blades, produces a reactive effort on these blades which turns the rotor of the turbine. This effect is very similar to that produced by water issuing from an ordinary hose nozzle.

In the turbines of the impulse type the complete expansion for any one stage takes place in the stationary blades or nozzle, and the steam is delivered to the moving blades with a velocity somewhat more than double that of the blades. The passages between the moving blades are of uniform, or even slightly increasing, cross-section from inlet to outlet. The moving blades check and reverse the velocity of the steam current and the reluctance of the steam current to having its direction and velocity altered gives rise to a force against the

blades which sets the rotor in motion.

In the all impulse type a considerable pressure difference exists between adjacent stages and inasmuch as the steam leakage increases as the square of the pressure drop it is very important that means be devised to minimize the leakage and resultant loss of

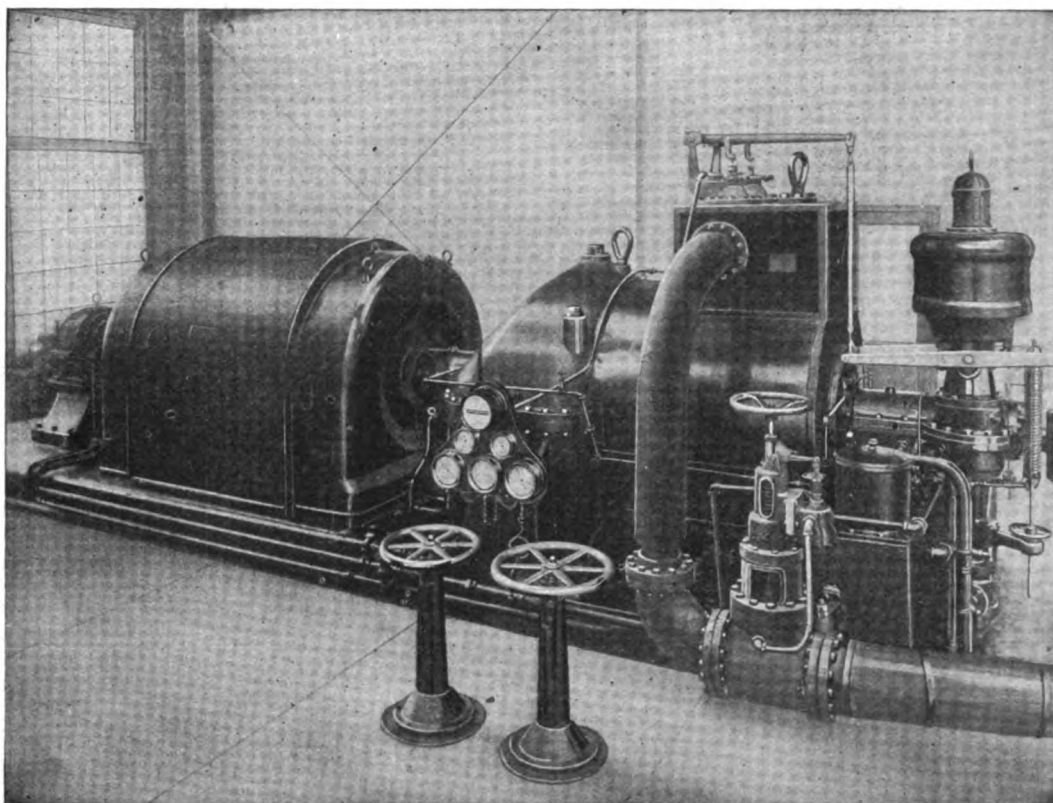


Fig. 2—1,875 kva, 60 cycle, 3 phase, 2,400 volt turbine generator unit.

efficiency. It has therefore been the universal practice in this type of turbine to employ a rotor built up of discs mounted on a through shaft of small diameter in order that the circumferential clearance between the shaft and the diaphragms separating the pressure chambers may be as small as possible. This construction results in a light shaft with considerable deflection, and the clearance must necessarily be great enough to allow for this deflection. The combined stresses, due to the high disc velocities employed and the temperature changes resulting from varying steam flow, require great care in designing and unusual skill in assembling the rotors to be assured that the discs are securely fitted to the shaft.

The use of a single-impulse element for the first stage of the expansion is desirable in many cases since it re-

places without any appreciable sacrifice of economy, a considerable number of rows of reaction blading in the least efficient part of a reaction turbine, and makes possible a shorter and consequently stiffer rotor. For the intermediate and low-pressure sections, in which the volume of the steam is sufficient to require reasonably long blades moving at considerable velocities and in turbines of large capacity requiring comparatively long first-stage blading, extended experience demonstrates that reaction blading has a decided economic advantage.

In the reaction type, the pressure drops between adjacent stages are very much smaller than in the impulse type so that the leakage losses between stages are considerably less. Turbines designed on this principle employ comparatively low peripheral velocities and a rotor

or pipe connections. With the special lifting gear furnished with each turbine as a part of the tool equipment, the rotor is removed in a very short time.

The operating characteristics of turbine-driven generators differ little from those of alternators designed for engine or water wheel drive. There are therefore no new ideas for the operator, familiar with slow-speed machines to acquire.

Turbine-generator design proportions, on account of the high operating speeds, are radically different, and the experience gained with the slow-speed types, is of relatively little value for the high.

Reliable and safe units require the use of exceptionally high grade, expensive materials; they are small in diameter and wide of core. These proportions in turn

introduce difficult problems in ventilation and heat dissipation.

Close-grained cast iron is used for the stator frame, and end bells of the same material are bolted to it to serve as a guide for the incoming cooling air, as well as to provide a protecting shield for the windings.

Transverse ribs in this frame are dovetailed to mount the armature punchings, and back of these ribs a large annular chamber collects the cooling air and guides it to a discharge opening. The air is usually discharged at the bottom of the frame,

but many stators are provided with a "chimney," and with these, air discharge is possible at either top or bottom.

The core is built up of thin sheets of a special grade of soft steel. These sheets are accurately punched to the proper shapes, and individually japanned. They are supported in the frame dovetails, and held tight under pressure by end plates secured with through bolts.

The armature coils are form wound and interchangeable. They are held in open slots in the core by wedges. The end turns are bent back at an angle calculated to give maximum heat radiating surface, and at the same time allow a very rugged coil bracing arrangement.

All current carrying conductors are carefully sectionalized in order to eliminate, so far as is possible, useless,

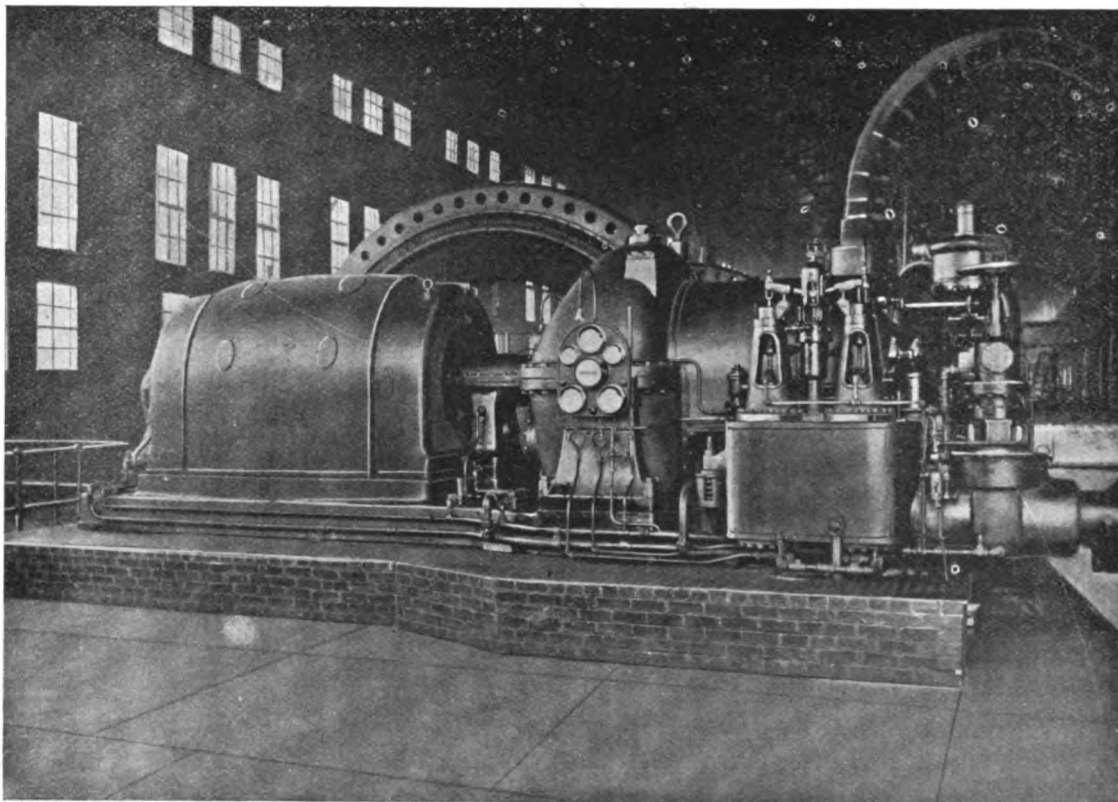


Fig. 3—A 2,500 kva, 2,000 kw, 3 phase, 60 cycle turbine generator.

built in the form of a hollow drum is readily adaptable. This construction being much stiffer than the shaft and disc design commonly used in impulse turbines. When a disc is heated, it develops internal strains that are impossible of calculation, and which are liable to start cracks in the metal, resulting, in many instances, in a complete rupture. On the other hand, in a rotor made up of a comparatively thin cylindrical drum of considerable diameter, and the rings of large bore, no such strains are encountered. Again, the drum construction of the rotor makes the turbine very much more accessible for examination and repairs. In most of the latter designs of Westinghouse turbines, constructed chiefly on the reaction principle, the upper half of the cylinder can be lifted without interfering with the governor, steam chest,

heat-generating eddy currents. Mica, a heat resistant, strong dielectric material forms a large portion of the coil insulation.

Clean cool air, in large quantities, is essential to successful generator operation. This cooling air is usually drawn into the machine by fans mounted on the rotor shaft. It may also be supplied, in the case of very large capacity units, by means of external motor-driven fans.

Steel, uniform in structure, and in quality, forms the body of all turbine-generator rotors. Single piece forgings are employed wherever satisfactory material in this form is obtainable. Where such forgings are not available, rolled steel plates, fastened to forged shaft stub ends are used. Individual pieces are carefully tested before assembly is started.

Slots for the field windings are milled into the surface of the rotor body. These slots may be parallel to each other in some two-pole rotors, or radically spaced as in others. When parallel slot motors are used, the end turns to the field windings fit under projecting poles and are thus protected from distortion under operation, due to centrifugal stresses. Where radical slots are employed, steel retaining rings or caps are fitted tightly over the end connecting sections for protection.

The field windings are made of heavy copper strap, laid into slots a turn at a time, and fastened securely in place. Fireproof insulation is used exclusively, both between adjacent turns and between coil and field body.

The rapid development in the last five years of very economical alternating current generation and transmission, makes a careful study of conditions and types of converting apparatus imperative, if the same relative efficiency is to be maintained. In addition to rotary converters, motor generators must be considered before a selection can be correctly and logically made.

If conditions are such as to require a rotary converter substation, there are a number of types of converters which can be economically used. The choice will depend largely upon the voltage, the nature of the load, the liability to heavy swings and overloads, the switching apparatus and the transformer equipment to be used.

The synchronous booster type of converter is proving highly efficient and reliable for general service.

These converters consist of a shunt-wound rotary converter in combination with an alternating-current generator mounted on the same shaft with the rotary converter and having the same number of poles. By varying the field excitation of this alternating-current generator the alternating-current voltage impressed on the rotary converter proper can be increased or decreased as desired. The direct-current voltage delivered by the converter is thereby varied accordingly. The principle of operation of the booster converter is therefore very simple and easily understood.

The direct-current voltage range can be made any desired value by properly proportioning the booster generator capacity. For extreme voltage special booster converters are required. It however, is rarely practic-

able to obtain more than 15 per cent buck or boost. The standard variation is a total range of 20 per cent, that is, 10 per cent below and 10 per cent above the average voltage for which the converter is designed.

Synchronous booster rotary converters are well adapted for any application for which a relatively wide variation, whether automatic or non-automatic, in direct-current voltage is necessary. They are particularly desirable for serving incandescent lighting systems where considerable voltage variation is required for the compensation drop in long feeders, for operation in parallel with storage batteries and for industrial work where extreme variations in voltage are encountered.

Compared with the transformer or induction regulator method, the booster method has the following advantages:

1. There is only one unit which requires minimum floor space and cable connections. This simplifies installations because there are no connections to make between several pieces of apparatus.

2. Rugged operating characteristics. With induction regulators dangerous forces may be developed between the stator and the rotor, if the converter is connected to the alternating current line while out of step.

Compared with the so-called regulating pole or split-pole converter, the synchronous converter has the following advantages:

1. Higher efficiency particularly at the lower voltages.

2. Better commutation, particularly at the maximum voltage and maximum load, when good commutating characteristics are especially essential. This advantage is further increased by the possibility of using commutating poles whenever large capacity or other conditions make commutating poles advantageous.

3. Smaller weight and floor space requirements particularly for 60-cycle units.

As made by one leading manufacturing company, 60-cycle motor generators have been standardized in the usual sizes up to and including 1,500 kilowatts. The motors are wound for 2,200 volts in all sizes; 220-440 and 550 volts for the 300 kilowatt size and below; 6,600 volts for 300 kilowatts and above, and 13,200 volts, and for 1,000 kilowatts and above.

The generators are wound for 250 volts in all sizes, 125 and 275 volts for 200 kilowatts and below, and 600 volts for all sizes of 100 kilowatts and above. Any 250 volt generator can, at increased cost, be arranged for three-wire service.

Standard synchronous motor generators consist of a self-starting, rotating field synchronous motor mounted on a common bedplate and shaft, with a direct-current generator. A direct-connected exciter for 125 volts is included where required, although the motor fields can be wound for 250 volts, if desired. The motor generators below 110 kilowatts have three bracket bearings and the ones above, up to and including 500 kilowatts have three, and above 500 kilowatts, two pedestal bearings.

Automatic Graduated Power Plant Control

System Which Gives Graduated Control—Controls the Fuel Feed and Damper Position Jointly So as to Correspond With the Load and Maintains Proper Relation.

By F. A. MORELAND.

DUE to the high price of coal and to the shortage of boiler room labor there has been a demand for equipment that would efficiently control the combustion in steam boilers by automatic means.

It is a well-known fact that if the load changes, it will affect the steam pressure. If the furnace conditions change, or if the feed water flow is changed there will also be a change in the steam pressure. It is impossible to find in the majority of plants, a fireman who will change the position of the damper more than a few times each day, and then only on very heavy load variations. Many firemen forget that there are dampers and never change them once during the day, usually leaving them wide open. The superintendent or chief engineer must be somewhat lenient with the fireman, due to

plants and forge shops where the load is continually up and down. The fireman does not know when the load is going to change and cannot be ready to meet the sudden changes, because the steam pressure gage does not show it quickly enough. The gage is usually placed so high or so far away that a change of a couple of pounds takes place before it can be noticed. Then there is a rush to offset it, with a corresponding fuel loss, due

to "steam production at any cost."

In blast furnace plants where the waste gas is used for steam production the gas comes over to the boilers under pressure and with a varying heat unit content. It has been impossible to get regulation that would control this fuel, because of the varying pressure and of the many variations in the heat unit content of the gas. These

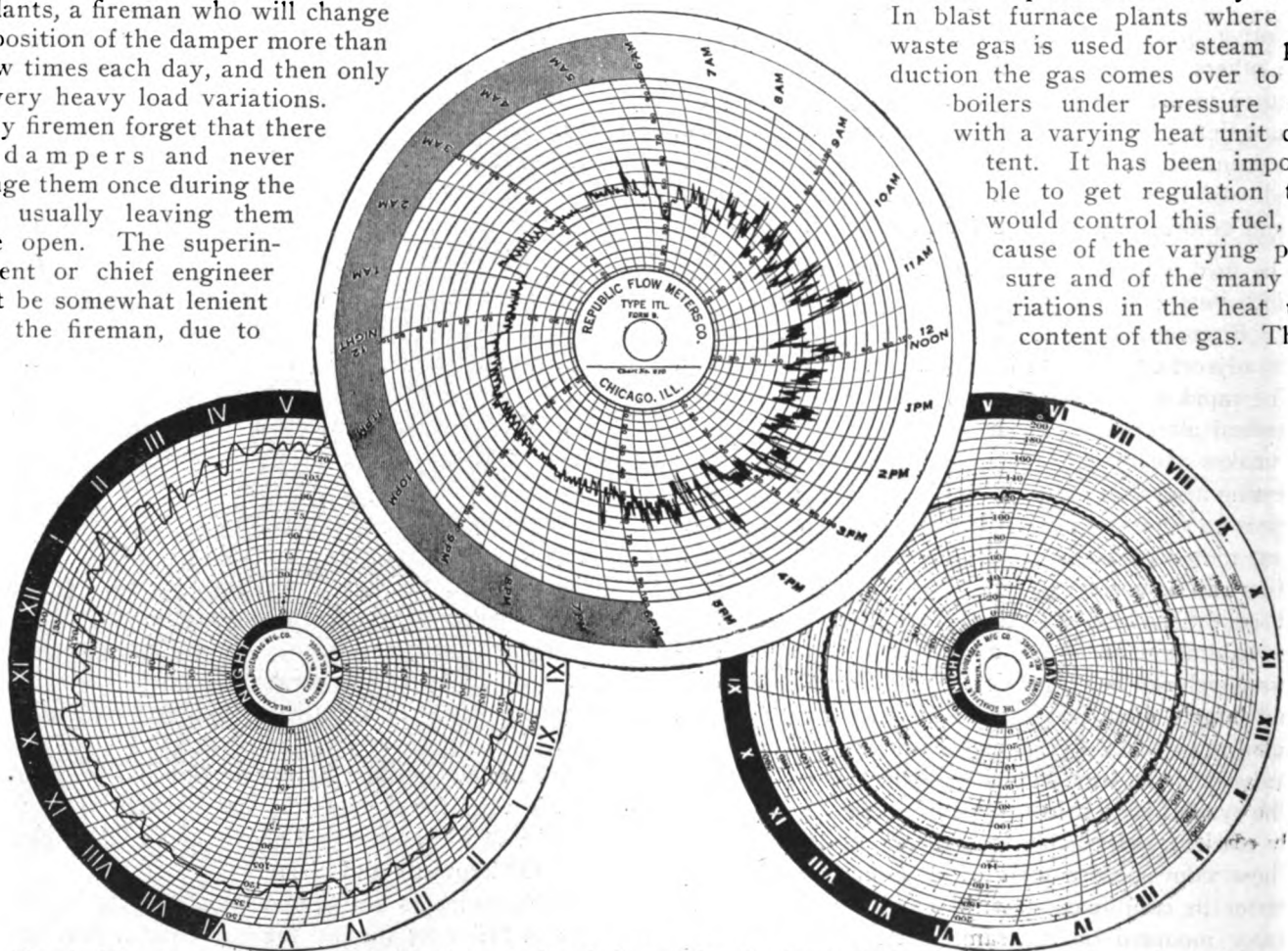


Fig. 1—The pressure chart with hand regulation indicated by the lower lefthand chart is typical of conditions before the Carrick combustion control was installed. Note extreme variations in pressure over a wide range. The upper chart shows the load for the day on which the pressure chart with automatic control (lower right hand) was taken. Note that the pressure is maintained within a definite range in spite of extreme variations.

the shortage of labor at present, and because the neighboring plant stands ready to offer him a position, and naturally the fireman becomes independent.

If the fireman only knew it, he would have less coal to shovel and fewer ashes to haul out if he would use his dampers a little more and save some of the coal that is now wasted through the heating of excess air.

Under manual control, there is usually a marked variation in the steam pressure, which is true in steel

fluctuations result in a varying steam pressure, and something is needed in the form of a control system that will handle this particular condition.

Improvement has been made in steam pressure regulation by the use of automatic damper regulators, but the engineers of the large power plants quickly recognized the inefficiencies of these regulators because most of them bring about the very troubles that they are designed to correct, and, because of that fact,

many stoker manufacturers have become dissatisfied with regulation. When there is a good bright fire on the grate and the load drops off, the steam pressure increases. The regulator closes the damper. Immediately the furnace is transformed into a gas producer, due to the extreme change in the air supply, which has been suddenly reduced, and carbon monoxide results in the flue gas. Then the load increases; the steam pressure drops and the damper is opened. The combustible gas bottled up in the boiler is released up the stack and there is a very decided waste. Burning fuel to CO produces only one-third as much heat as when burned to CO₂.

Upon examining any steam pressure chart under this system of regulation it will be found that while the pressure is fairly uniform, the steam pressure curve is made up of fine saw teeth, indicating many changes, and in every hour there are anywhere from 15 to 20 such sudden changes, or on an average, one every three or four minutes. These regulators at the beginning operate on a pound or two, but with age they change to four or five pounds because of the care required, but which they do not get.

A system has been designed which will give the graduated control that engineers have been waiting for. It controls the fuel feed and damper position jointly so as to correspond with the load, holding the proper relation for efficient results. Due to a graduated movement it takes and holds any intermediate position that is required for the load carried and instantly moves to a new position if there is a slight change in the load or steam flow, in feed water, or in furnace conditions. This system maintains a proper relation between fuel and air supply by individual control of stoker engines, motors, dampers, oil burners, forced or induced draft

fans. Instead of operating between the two extremes of wide open and tight shut, it takes the intermediate position between those points that is necessary for the particular load or condition at that time. This control system referred to is known as the Carrick Combustion Control, which consists of a master control with a barometric column of mercury using the steam pressure to actuate the travel of the mercury instead of atmospheric pressure. The column of mercury is two inches high for every pound of steam pressure, so that for every ounce of pressure change there is 1/16 of an inch of mercury travel.

The mercury reservoir, shown in the lower left hand corner of Fig. 2, is connected with the upper mercury cylinder or well by a pipe line and in the upper well there is a free moving plunger which, by means of a yoke and side rods, is connected to the arm of the hydraulic cylinder, shown at the right hand side of the lower panel. The chain connection between the floating plunger yoke and the hydraulic piston passes around the floating wheel lever or valve gear shown in the center of the lower panel. Just below this wheel lever, and directly connected to it is shown a four-way pilot valve which controls the flow of water from the pressure either to the top or bottom of the hydraulic cylinder, depending on whether the pressure rises or falls, thus raising or lowering the piston of the valve. It will be noticed that the wheel lever is free to move in a rotating motion as well as up and down, due to a slot provided in the bracket supporting the wheel. It will also be noted that the hydraulic cannot move until the four-way pilot valve is opened, as until this is done there will be no

water flow to move the hydraulic piston. Assuming an increase in pressure, it will immediately increase

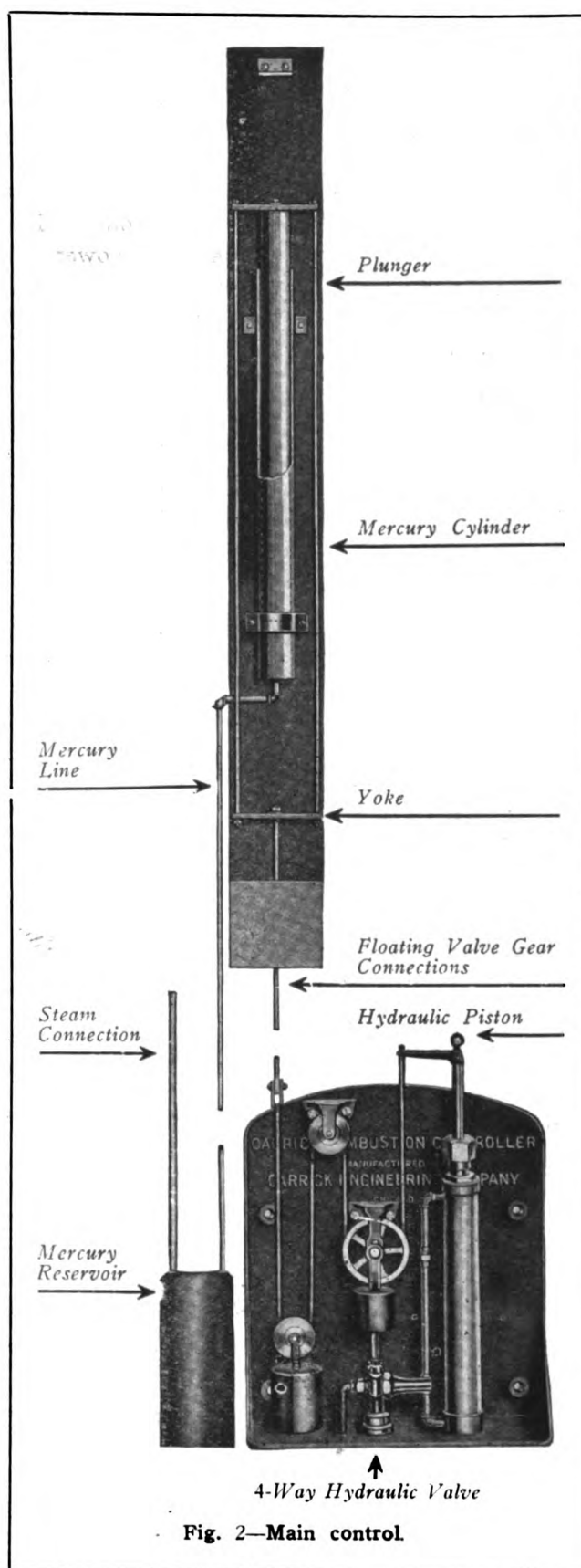


Fig. 2—Main control.

the mercury level in the upper well or cylinder; the plunger will rise just as soon as the change in steam pressure reaches one ounce, the movement being $1/16$ of an inch. This will raise the wheel lever, slightly turning the wheel and at the same time raising the entire lever and valve piston, as the hydraulic must remain stationary until the above operation takes place. Immediately upon the piston of the pilot valve being raised, water from city pressure is admitted to the top of the hydraulic cylinder, causing the piston to move downward, lowering that side of the wheel lever and automatically returning the piston of the pilot valve to a neutral or closed position, as soon as the hydraulic piston travels downward as far as the floating plunger travels upward, or in other words when the hydraulic is balanced against the mercury, which means balanced against the steam pressure.

When this balance takes place the master control holds that position until there is another change in pressure. A drop in pressure operates just the reverse. The plunger is lowered, the piston of the pilot valve is lowered, water is admitted to the bottom of the hydraulic cylinder and the hydraulic piston moves upward, pulling the valve piston back to neutral, when there is a balance between the plunger and the hydraulic.

The operation of the master is then transmitted to each individual auxiliary, there being one auxiliary for each individual damper, stoker engine or motor, forced draft fan, etc. These auxiliaries are all connected to the master by a strong tiller rope cable, or chain, and the connections are run through conduit pipes with special conduit pulleys so constructed as to make it possible to turn an angle of any degree.

Where an auxiliary is installed, a special insert is provided so that a break can be made in the main conduit line and a branch cable taken off for the auxiliary. As the master moves, each auxiliary moves, thus giving individual control to each particular part of the equipment that enters into the combustion process.

Prominent engineers have been closely watching the results from the use of this system at the Edison building and the Railway Exchange building in Chicago. These plants are used as central heating stations and the charts herewith show a comparison of load, with steam pressure chart before and after installation of the automatic graduated control system (Fig. 1). The upper chart in the center shows the load conditions. The chart at the right shows the steam pressure chart from the same boiler for the same day. Note that the line is a floating line and does not show the saw teeth that are so characteristic with wide open and tight shut regulators. The range is set for five pounds, but any range can be obtained with the graduated control, due to the adjustment features which it has. The chart on the left shows the pressure chart before the installation of graduated control was made.

One of the features of this graduated control is the adjusting set that is used on each auxiliary. By means of this adjuster one boiler can be set ahead or back of the others, and the load can be carried on a certain number of boilers up to a predetermined rating and the other boilers can then be automatically cut into service and at any rate desired.

One of the most interesting records is a comparison of the load and position of the damper on a 500 hp B. & W. boiler. The load chart, Fig. 3, shows the boiler horsepower load (multiply by 10), and just above it is the chart showing a corresponding damper position record.

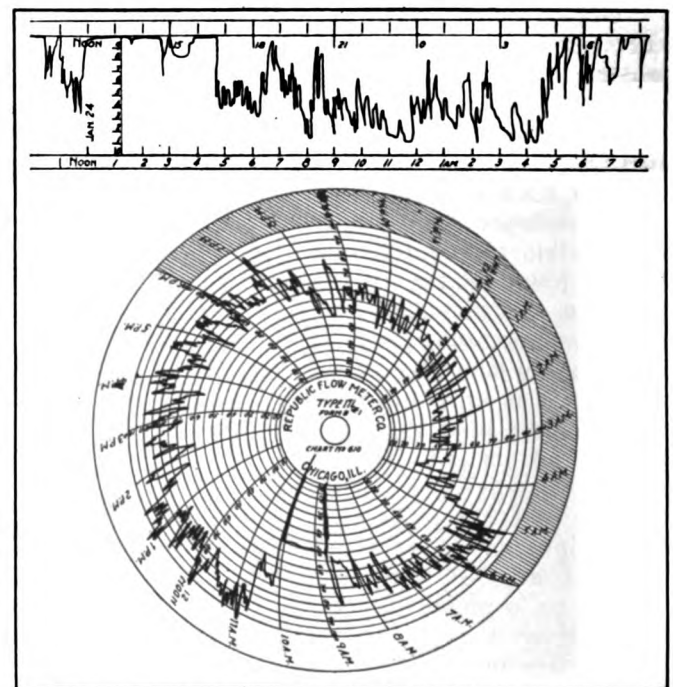


Fig. 3—Comparison of load and position damper on a 500 hp B. & W. boiler. The load chart shows the boiler horsepower load (multiply by 10) and just above it is the chart showing a corresponding damper position record.

Note that at 7 P. M. for the load of 900 hp the damper is nearly wide open. From then until about 8:30 the load diminishes and the damper position changes to correspond exactly. Also between 4 and 5 o'clock the next morning the load gradually increases, and again the damper changes its position, gradually opening up little by little until when the peak is reached the damper is in the right position to carry the rate of combustion that will enable the boiler to carry the load efficiently. The speed of the stoker has been increased in the same proportion so that the efficient relation between draft and fuel bed established for the grade of coal burned, has been maintained automatically and with closer precision than is possible with hand or any other regulation or control.

Losses from Long Superheat Steam Pipes Determined by Means of Curves

Curves Save Laborious Calculations and Offer Ready Means to Compute Heat Losses From Pipes When Contemplating Use of Superheated Steam.

By THOMAS G. ESTEP.

MODERN central stations are using steam at higher pressures and temperatures than the older ones and are securing by this means a marked increase in efficiency. The theoretical gain, due to higher steam pressures, is somewhat larger than that obtained in actual operation but within certain limits there is an ultimate saving, even after greater first cost is taken into consideration.

With superheated steam the theoretical gain due to superheating is rather small but the actual gain is comparatively large. This difference between theory and practice is brought about by assuming that the theoretical prime mover operates on a non-conducting cycle and that the only heat loss is that which is carried away by the exhaust steam. In the actual prime mover, the cycle

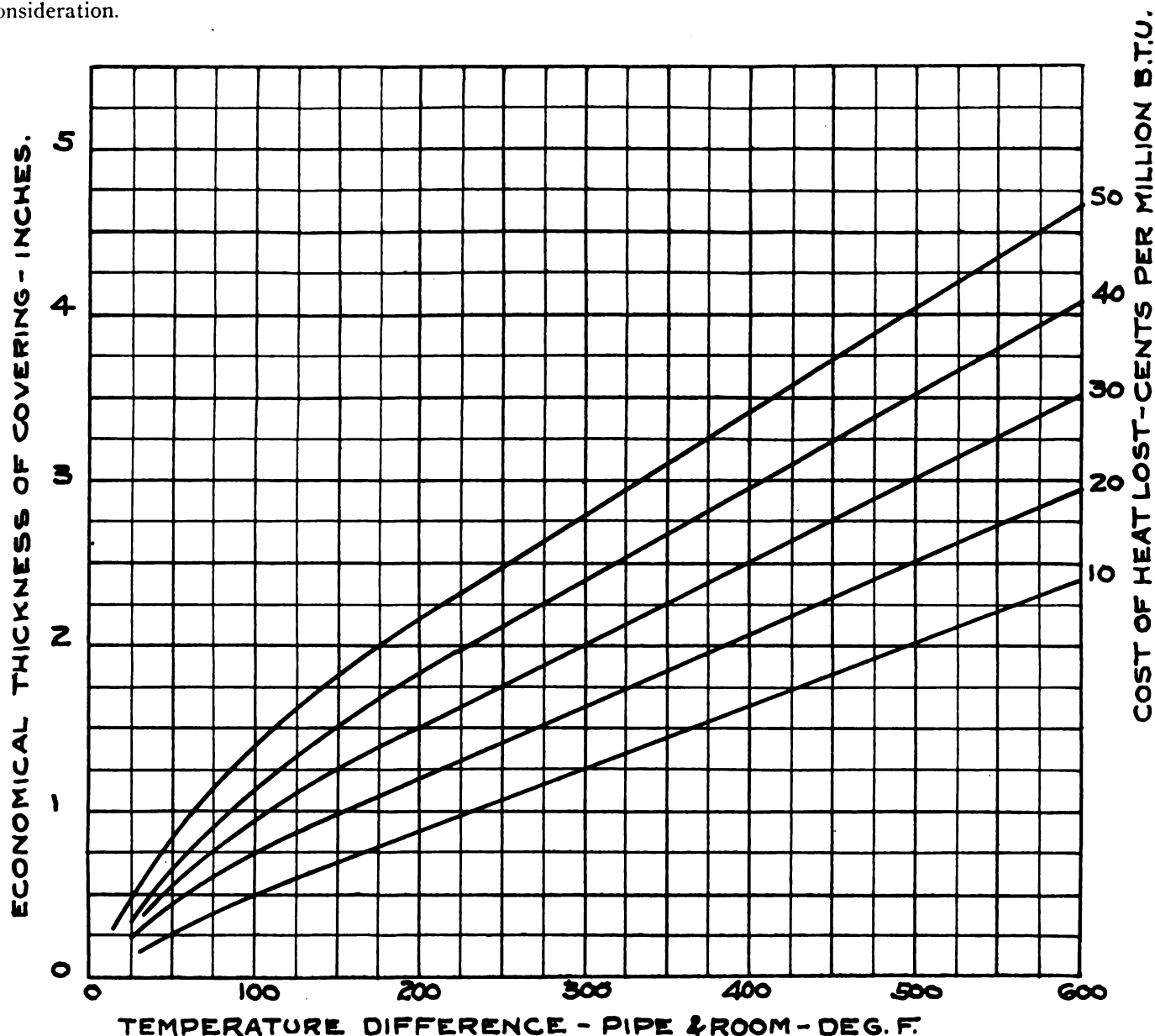


Fig. 1.

Curves showing the most economical thickness of pipe covering for various temperature differences and heat costs.

is not non-conducting and there are other losses besides the heat in the exhaust. In the reciprocating engine the increased gain due to superheating is due largely to reducing cylinder condensation and in the steam turbine the increase in efficiency results from reducing windage losses and causing condensation to occur later in the expansion.

Theoretically the gain due to superheating amounts to about 1 per cent for each 35 degrees of superheat while actually it is about 1 per cent for each 8 to 10 degrees. In the low pressure turbine the gain is even greater.

The steel plant engineer has been watching with much interest the developments in the central station and has

been seriously considering the application of some of these developments to his own plant. In the power plant already installed there is not much opportunity to increase the steam pressure but very few changes are necessary to secure and use superheated steam.

In the steel mill power plants which have been built recently, are usually found all of the modern improvements, such as higher steam pressures and temperatures, larger boilers and higher ratings and both high and low pressure turbines.

If, however, it is the intention to improve by the use of superheated steam, the efficiency of a less modern plant, where the main power units are not grouped near

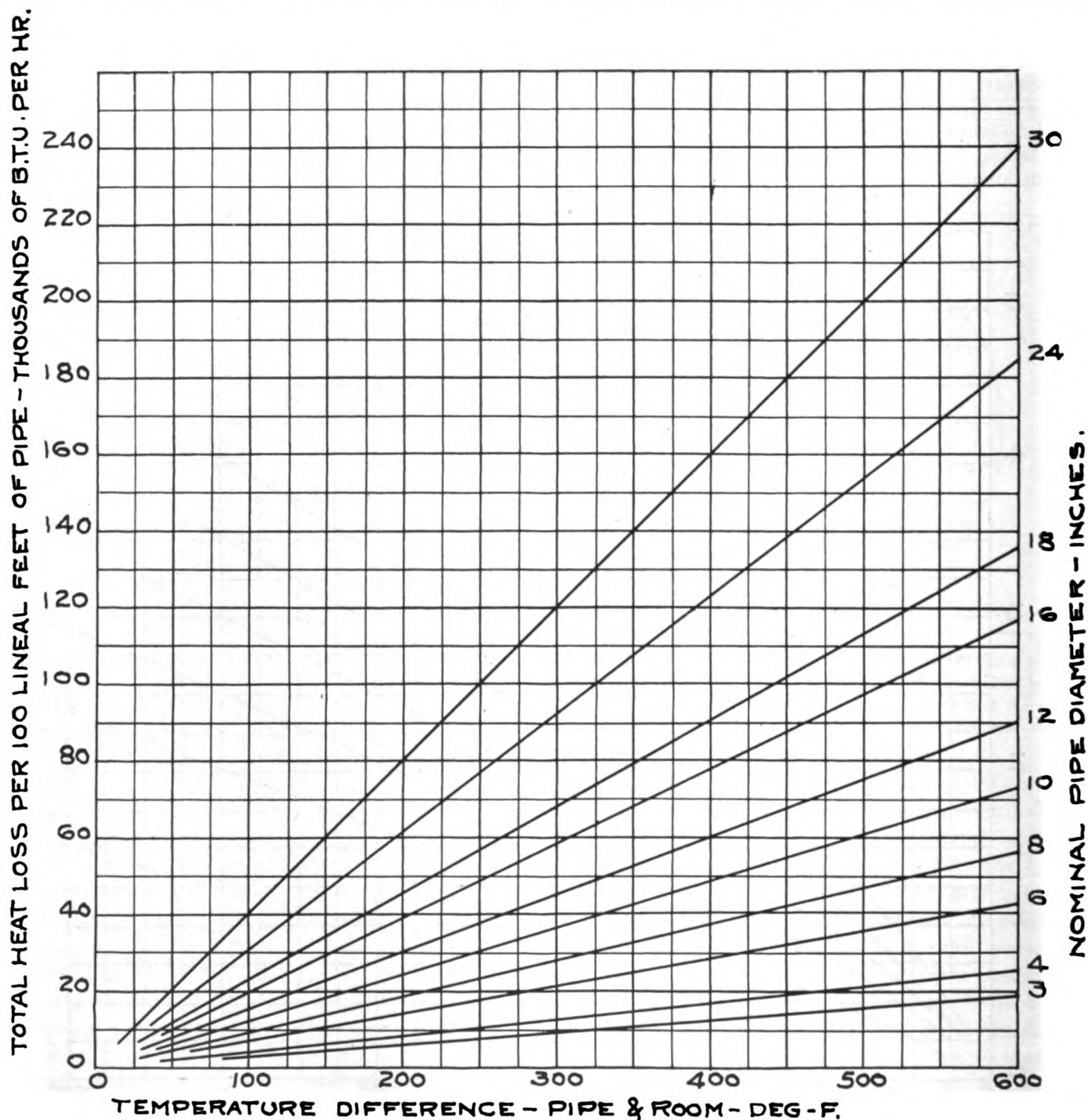


Fig. 2.
Curves showing the total heat loss per 100 linear feet of pipe in Btu per hour when covered with the most economical thickness of pipe covering.

the boilers but are widely scattered through the plant and long steam lines are necessary, the results may be disappointing.

Failure to obtain central station economies is largely due to the loss of superheat in the long steam lines. These lines are usually covered with the proper thickness of covering for the saturated steam temperature and when superheated steam is used, the difference in temperature between the pipe and the room is greatly increased, thus increasing the rate of transmission through the pipe covering.

In many cases, if a calculation is made, it is found that nearly all the superheat is lost by transmission from the pipe line by the time the steam has reached the engine or turbine.

It is very advisable to make such a calculation before taking any definite steps toward using superheated steam in the old plant but the engineer will find that to arrive at any result, that certain factors must be known or as-

sumed and probably a great deal of time will be expended in going over the mass of discordant data on heat transmission through pipe coverings in order to determine those which are most reliable and applicable to the particular case in hand.

The following curves are presented so that it will be possible to determine approximately the losses from steam pipes without any laborious calculations and furnish the engineer with a ready means of taking into consideration this important item in the contemplation of the use of superheated steam.

Curves of this nature must of necessity be of an approximate nature for there are so many variables in the problem that to take them all into account would be an impossibility and still have the curves apply to a general case so that it must be understood that the results plotted are valuable for estimating purposes only and if more exact information is desired, each particular case must be solved independently. (Continued on page 263.)

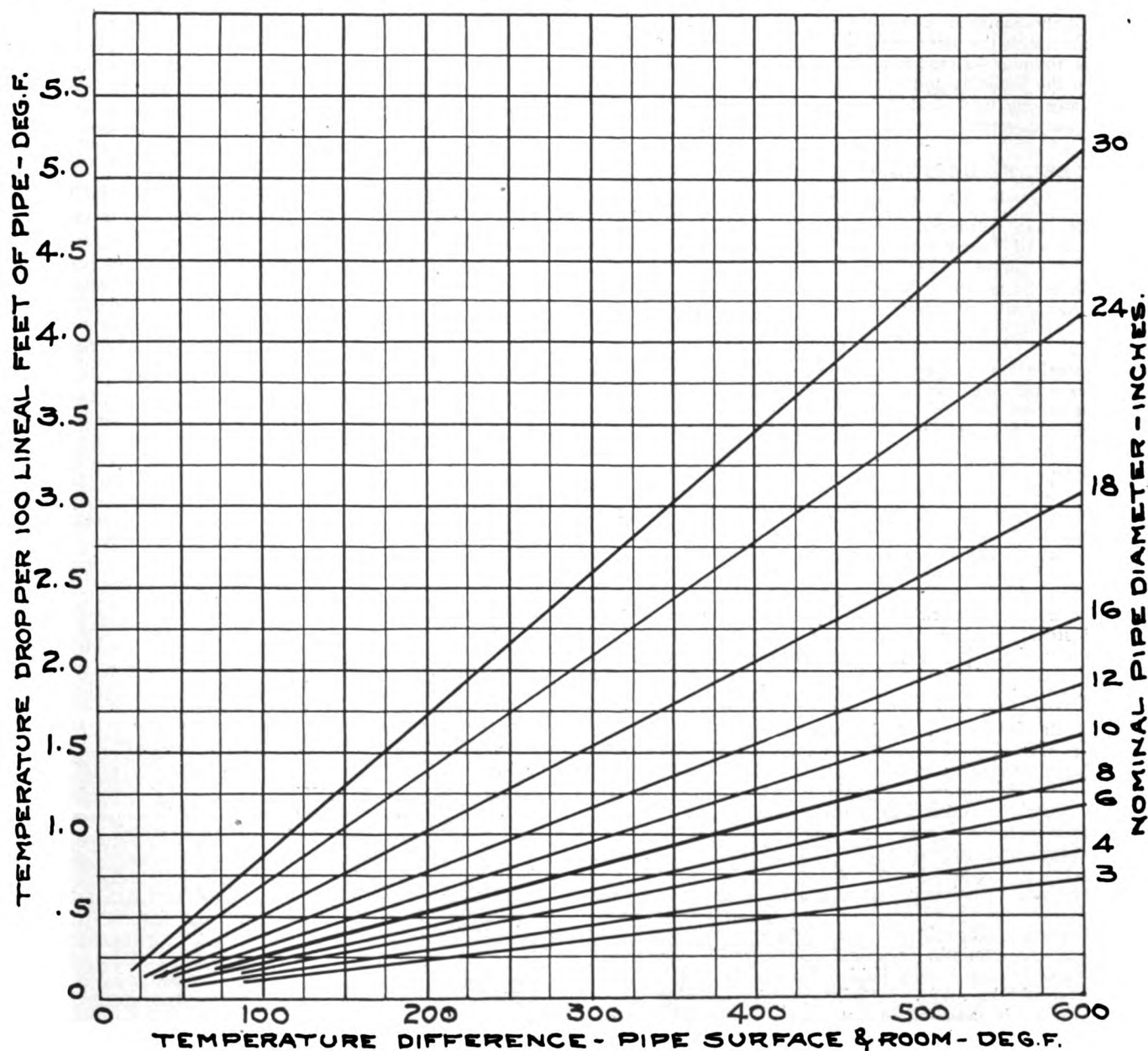


Fig. 3.

Curves showing the temperature drop per 100 lineal feet of pipe when covered with most economical thickness of pipe covering.

FOREIGN RELATIONS

IRON AND STEEL SITUATION IN CANADA.

(Consul General J. I. Brittain, Winnipeg, Manitoba)

The serious condition of the steel industry in Canada resulting in mills not being able to fill orders is described by the Financial Post as follows:

It is useless to try to disguise the fact that there is a serious situation right here in connection with the supplying of steel and iron to Canadian industries. What is adding to the seriousness of the outlook is the difficulty that Canadian steel mills are experiencing in securing supplies of coal to keep their plants in operation. Much of this is being confiscated before it ever reaches the border, and as a result, curtailed operation is necessary, and this at a time when the mills are booked for months to come with insistent and urgent tonnage. Several Toronto buyers have been in the steel mill district of the States during the last few days, and they have all returned with the same reports. They went in an effort to get their tonnage—already on the books—advanced a little nearer to the finishing mills, or to find if it were possible to pick up any odd lots of steel that might be available. They failed in both.

STEEL SITUATION IN GREAT BRITAIN.

(Trade Commissioner Wilbur J. Page)

January has witnessed a pronounced revival in most of the branches of British steel making and holds out fair prospects for the future. The conclusion of the protected molders' strike is by far the brightest feature of the developments during the month in England, although it will take many weeks to overcome the stagnation and congestion caused by the strike.

The steel trade has not been nearly so busy as have the industries producing finished tools. With the cancellation of munition orders the production of crucible steel was greatly curtailed, and it is only recently that there has been a satisfactory revival in production. It is interesting to note that at the present time the majority of the crucible furnaces are working a full week. The steel trade as a whole needs, more than anything else, increased orders for high-speed steel. The large stocks held by the Government at the time of the armistice have gone a long way toward supplying the brisk demand for home consumption. Steel producers are looking to the American markets somewhat hopefully for an increased demand for Sheffield tool steel. The export demand for tool steel at present (last of January) is better than it was at any time during the past year. Yet, despite the brighter outlook, the position is far from satisfactory from the makers' point of view.

Alloy, Open Hearth, and Mild Steels—New Rod Mills.

The demand for alloy steels has been slight, except with a few large producers who have practically controlled the demand from the automobile industry. This latter industry and the electric engineering trades have furnished steel producers with a large volume of business.

It is estimated in the Sheffield district that the output capacity for open-hearth acid and basic steel has so greatly increased since 1914 that it will take a very large and steady demand to keep production up to normal capacity. Business during the past year did not suffice for this. Shortage of orders was not altogether responsible, but rather a shortage of rolling-mill capacity available to manufacture steel as fast as it could be made.

The foreign demand for mild steel at the close of last year was very insistent and makers of this class of steel are well booked up with orders for some months to come.

Among recent additions to equipment for steel production has been the installation of two new rod mills by the Sheffield Rolling Mills Company.

Hadfield (Ltd.) have ordered two additional rod mills for their works, and another plant has ordered two, as well as a cogging mill. In the Sheffield district easily the event of 1919 was the opening of the Temple Burrough, a continuous-wire rolling plant, which has a capacity for turning out 1,500 tons of finished rod a week.

Electric Furnaces—Shortage of Needle Wire.

Electric furnaces have had more than their share of idleness in the last few months. Many of the smaller ones installed during the war to produce tool or alloy steel have remained idle a large part of the time during the armistice. The larger ones, however, have done fairly well. Edgar Allen & Co. have decided to erect two new steel furnaces, while another concern in Sheffield has decided on the erection of a large electric furnace of the Heroult type.

A brisk call for rolling stock speaks well for the future production of those plants which make railway axles and springs. This is the more welcome as such plants have not been running to capacity during the last 12 months. The Don River plant of Vickers (Ltd.) has just started a large new factory for the making of files and has also introduced the manufacture of hack-saw blades and hand-saws.

THE BELGIAN STEEL AND METAL INDUSTRY.

(Consul General Henry H. Morgan, Brussels)

According to the report of the inspector general of mines a battery of 20 coke ovens has been put into operation at the Charbonnage de Belle Vue at Elouges; another at the Havre division of the Charbonnages de Bois-du-Lac. The sheet-rolling mill of the Sambre et Moselle Company (Chate-lineau division) was put into operation in October.

Blast Furnaces and Zinc Ovens in Operation.

One of the three blast furnaces at the Usines Metallurgiques at Hainaut suspended operations owing to a lack of ore. A second blast furnace was put into operation at the Ougree Marihay plant, but the irregularity in the supply of coke and ore are hindering the operation of the blast furnaces, which, however, are producing 300 tons a day. At the steel plant of the same company a new rolling mill has been put into service.

The metallurgical company of Corphalie has lighted a zinc oven, the Laminne Company four ovens, and Dumont Brothers, at Sclaigneaux, 10 zinc ovens producing 228 tons a month and a medium blast furnace producing 10 tons of lead a day. The Vieille Montagne has put additional ovens into operation and at present has 18 active at Flone and 32 at Valentin-Cocq.

IRON AND STEEL INDUSTRY OF HUNGARY.

According to a cablegram received from Budapest, under date of February 22, the iron industry of former Hungary produced yearly 20,000,000 metric quintals (1 metric quintal = 220.46 pounds) of iron ore; the only remaining mine, at Rud-Banya, can produce less than 4,000,000 quintals and, it is alleged, will be exhausted in eight years. Of the former iron and steel industry, 40 per cent is left to new Hungary against its 23 per cent of raw material, so that 10,000 workmen will be out of work. A furnace and rail mill that formerly employed 4,000 workmen is now entirely without ore because the mines and fuel are now in Czechoslovakia. Of the engineering industry, most important in old Hungary, with a yearly production valued at 212,000,000 crowns and with 41,000 employes, 90 per cent will be left with less than 20 per cent of the necessary raw material.

The above communications are published as they were reported in the daily "Commerce Reports."

PRODUCTION TOPICS

LOSSES FROM LONG SUPERHEAT STEAM PIPES DETERMINED BY MEANS OF CURVES.

(Continued from Page 261)

It will be assumed in the following that if it is contemplated to use superheated steam, if the existing covering is not of the proper kind or thickness that it will be removed and the right material and thickness substituted.

The first thing to determine is the proper kind of pipe covering to use. This is comparatively easy and there are a number of good materials on the market. In most cases the choice lies between 85 per cent magnesia and diatomaceous earth covering and as far as efficiency is concerned, there is not a great deal of difference between the two.

The next step is to select the proper thickness of covering. The coefficient of heat transmission is almost inversely proportional to the thickness so that the thicker the covering the less will be the loss but the more expensive the covering. There is a point where the yearly cost of the covering will just balance the saving in heat. This is known as the most economical thickness of covering.

The curves shown in Fig. 1 are plotted from data furnished by the Armstrong Cork & Insulation Co., of Pittsburgh, and give the economical thickness of covering for various fuel costs and temperature differences. These curves are worked out on the following assumptions. The cost of covering is the erected cost at present prices. The interest and depreciation charges are 15 per cent yearly and the cost of heat is the cost of the heat in the steam pipe, a boiler efficiency of 75 per cent being assumed.

From these curves the following thicknesses were selected and used in the subsequent calculations and are based on a heat cost of 30 cents per 1,000,000 Btu. The nearest commercial thickness was taken instead of the fractional thickness from the curve.

Table of Covering Thickness Used in Calculations.

Pipe Diameter Inches	Temperature Difference, Pipe & Room, Deg. F.					
	100	200	300	400	500	600
3.....	S.	S.	1½	2	D. S.	3
4.....	S.	S.	1½	2	D. S.	3
6.....	S.	S.	1½	2	D. S.	3
8.....	S.	S.	1½	D. S.	D. S.	3
10.....	S.	S.	2	D. S.	D. S.	3
12.....	1½	1½	2	3	3	3
16.....	1½	1½	2	3	3	3
18.....	1½	1½	2	3	3	3
24.....	1½	1½	2	3	3	3
30.....	1½	1½	2	3	3	3

All thicknesses in inches.

S = standard thickness.

D. S. = double standard thickness.

After the above thickness was decided upon, the next step was to calculate the heat loss for the various size pipes selected and for the assumed temperature differences. The determination of the coefficient of conductivity to be used was not an easy matter because the results of experiments on this point are rather discordant. Probably the most accurate data available are those from the experiments of McMillan, (American Society Mech. Engrs., 1915), Randolph, (General Electric Company), Armstrong Cork & Insulation Co., and Franklin Manufacturing Company.

The coefficients finally selected are no doubt uniformly a little high but it was thought that it would be best to err on this side rather than have them too low.

The conductivity of a given material varies with the thickness, the temperature difference and the pipe size. In the calculations for the curves in Fig. 2, the covering was assumed to be similar to Nonpareil or 85 per cent magnesia.

Since the thickness of the covering increased with the temperature difference, the coefficient did not vary greatly with the temperature difference so that an average was used in order to reduce the amount of calculation. The coefficient was figured, however, for different pipe diameters.

From the above assumptions the curves in Fig. 2 were calculated and give the heat loss in Btu per hour per 100 lineal feet of pipe. If the pressure and temperature and weight of steam flowing are known, it is a very simple matter to find the drop in temperature for the heat loss taken from Fig. 2.

The curves in Fig. 3 can be used for making a rough estimate of the temperature drop in 100 lineal feet of pipe. The assumptions made in plotting these curves are as follows: Steam velocity, 6,000 feet per minute, specific volume of steam, 2.8 cubic feet per pound, (this corresponds to 175 pounds per sq. in. gauge pressure and 100 degrees superheat) and the specific heat of superheated steam .55. The actual conditions may be far from the above assumptions, so that the curves must be used advisedly. Note that a steam velocity of 6,000 feet per minute was used, which is about a maximum, so that the actual temperature drop will never be less than given and in most cases will be more. These curves, of course, do not apply after the steam has become saturated. The curves in Fig. 2 are recommended for more accurate work.

PRESENT STATUS OF NICKEL-CHROMIUM ALLOYS.

(Continued from Page 251)

Heat resisting devices, such as gauze, triangles and tongs. Castings to support apparatus in heated regions. Protected tubes for thermo-couples. Carbonizing boxes. Branding irons. Heated rolls. Wire and extension wire for thermo-couples.

There are hundreds of special uses for the alloy, some of which are known and many of which are yet to be discovered. Nearly every day some new application is found and there would be many more if the wants of the trade could be more generally known.

Application of Nickel-Chromium to Pyrometry.

The application of nickel-chromium to pyrometry deserves a little more attention.

Base-metal couples are rapidly replacing platinum couples for temperatures up to 2,300 degrees F. The same statement may be made for this subject as for industrial and domestic heating. The general use of pyrometers today, and the great advantages all over the country due to their use, was made possible by the development of nickel-chromium element for the base-metal couples. In the first place, it is certain that the development of pyrometry would never have been made with platinum couples as the foundation. In the second place, there is no pair of couple elements except "Chromel-alumel" which would have given to the public the confidence in the base-metal couples. The secret of success lay in the development of a good positive element. The negative element is easily taken care of with an alloy consisting mostly of nickel. The positive element is made of about 90 per cent nickel and 10 per cent chromium. Both the positive and the negative are very resistant to oxidation, both have high melting points and by proper care they can be produced in pairs to give a guaranteed millivoltage. When used under oxidizing conditions and protected from reducing gases, the temperature-millivolt relation is remarkably constant at all immersions.

NEWS OF THE PLANTS

The Trumbull Steel Company, Warren, O., has construction work well under way on an addition to its plant, to be used as a rolling mill. The installation will comprise nine-inch and twelve-inch Morgan type continuous hot rolls strip mills. The capacity of the cold rolled strip steel department is being increased, and it is proposed approximately to double the output of this branch. On completion of the new installation the company will have an annual capacity of about 150,000 tons of strip steel.

The Pittsburgh Open Hearth Steel Company, House building, Pittsburgh, Pa., recently organized, has broken ground for the construction of its new plant near Canonsburg, Pa. The company has a site of about 70 acres at this place, and plans for the erection of a plant with daily capacity of about 160 tons of universal and grooved rolled steel plates and hot finished strip steel. The initial plant unit will comprise a main building 80 x 400 feet; this mill will be equipped with one stand of 34-inch roughing mills, one stand of 24-inch duo mills with repeater, and one 22-inch finishing mill. A 2,000 hp electrical installation will be made, and the mills operated by electric drive. The works will also comprise three 20-ton gas producers, electric traveling crane of large capacity, two heating furnaces with charging machine, and other equipment. The company's product will be supplied either pickled and limed, or pickled and oiled, as orders may be received. J. H. McCloy is president, and H. J. Cowles, treasurer.

The Baltimore Copper Smelting & Rolling Company, Canton, Md., has completed plans for the erection of a one-story addition to its plant for increased capacity. The structure will be about 204 x 309 feet, and will be equipped as a rolling mill; it will be located at the intersection of First and Second streets, and is estimated to cost about \$30,000, including equipment.

In connection with the purchase of the C. D. Pruden Company, Baltimore, Md., by the Blaw-Knox Company, Pittsburgh, Pa., plans are under way for the construction of an addition to the Baltimore plant, to be used for the manufacture of standard steel buildings for industrial works, warehouses, etc. It is planned to break ground for the proposed addition at an early date, and the works will be fully equipped in the different departments of operation.

The National Tube Company, Frick building, Pittsburgh, Pa., a subsidiary of the United States Steel Corporation, has announced that plans have been perfected for the construction of a large tube manufacturing plant at Gary, Ind. It is proposed to break ground at an early date, and the works are estimated to cost in excess of \$25,000,000, including equipment. The project will include four large blast furnaces, a number of extensive tube mills, shops, and other plant structures. The works are being designed to give employment to close to 10,000 men.

The Whitaker-Glessner Company, Wheeling, W. Va., has arranged for the immediate construction of a number of additions to its plant, as well as extensive improvements and alterations in existing structures. The expansion work at the present time will be concentrated at the Portsmouth, O. works, which was formerly operated under the name of the Portsmouth Steel Company, and now specializes in the manufacture of steel barrels, range boilers, and similar equipment. The project is estimated to cost about \$120,000, including new machinery installation, and it is planned to have the structures ready for operation early in June. This branch of the

company is now giving employment to about 5,000 persons, including blast furnace, open hearth, fabricating, and other departments.

The American Steel & Wire Co. is arranging for the construction of a new blast furnace at Donora, Pa., to be located near its two blast furnaces now at this location. The new furnace will comprise a 500-ton stack, with ore bridge, ore bins, and other equipment, and it is estimated to cost about \$500,000, complete. The new furnace will be used to furnish metal for the company's open hearth plant at this place.

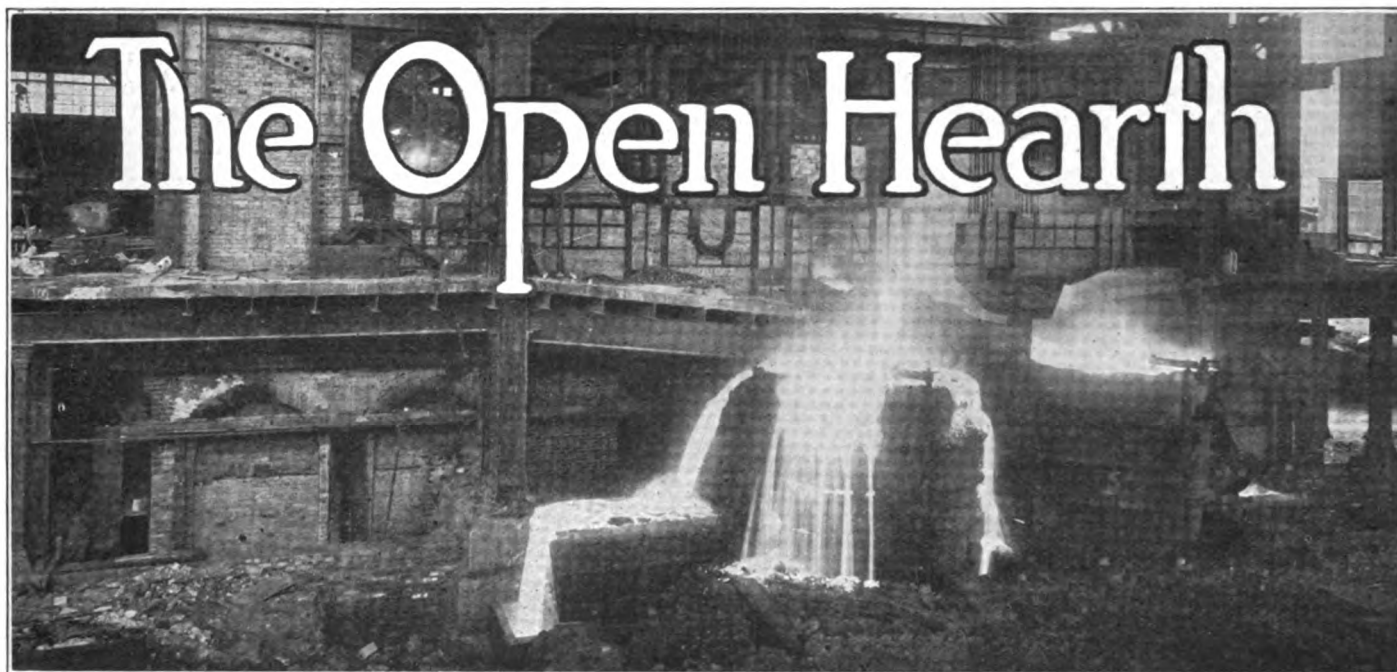
The Drain Steel Company, Perry building, Philadelphia, Pa., organized during the fall of last year for the manufacture of carbon and alloy steel products, is planning to commence active production during the present year. The company has acquired a site at Moore, Pa., and the first unit of the proposed new plant will have a capacity of about 75,000 tons of open-hearth steel per year. A number of open-hearth furnaces are now in course of construction, as well as other buildings at the works.

The Empire Steel & Iron Co., Catasauqua, Pa., has construction work under way on a new blast furnace with daily capacity of about 450 tons. The plant will be equipped with skip hoists, revolving top, ore bins, etc., and is expected to be ready for service early in May.

The Aetna Iron & Steel Company, Gary, Ind., has construction work well under way on a new plant in this vicinity. The company has a site of about 400 acres, and the entire works will comprise four complete units. The initial unit will consist of a main building, 88 x 252 feet; six sheet mills, and equipped with two electric traveling cranes of 30-ton capacity. Other buildings will include a furnace house, 53 x 550 feet, an annealing works, galvanizing plant, and warehouse, 84 x 625 feet. This latter structure will be provided with a large electric traveling crane.

T. W. Allison, head of Allison & Co., Chester, Pa., specializing in the manufacture of forging furnaces, has organized a new company to be known as the Allison Steel Products Company. A site has been acquired at Second and Palmer streets, Chester, and a new plant will be erected for the manufacture of steel specialties, including steel sash and kindred products. The initial plant unit will be about 60 x 200 feet, and the building contract for this structure has been awarded to the Chester Construction Company. The building is estimated to cost about \$70,000, and about \$30,000 will be expended for new machinery and equipment. This unit will be supplemented by other buildings at a later date. It is planned to inaugurate active operations early in May. It is proposed to develop an output aggregating about \$1,000,000 in valuation during the first year.

The St. Louis Coke & Chemical Co., Granite City, Ill., is planning for the operation of its new blast furnace at the earliest possible date. The foundation work has been completed, and superstructure work is under way. The plant will have a capacity of about 500 tons, and the larger portion of the output will be utilized by the Granite City Steel Works, a subsidiary of the National Enameling & Stamping Co., St. Louis. The company is also erecting a large battery of by-product coke ovens. It is understood that plans are under way for the erection of additional blast furnaces in this same vicinity at a later date.



H. J. McKnight, formerly connected with the traffic department of the Brier Hill Steel Company, has been made traffic manager of the Newton Steel Company, Newton Falls, O.

V V

C. F. Mackey, formerly assistant general manager of the Franklin Steel Works, Franklin, Pa., has been appointed manager of that company, succeeding Edward E. Hughes, who has withdrawn from active management, although he is still retained by the company in an advisory capacity.

V V

Carroll Burton has been named president of the Lorain Steel Company, Johnstown, Pa., succeeding I. Lamont Hughes. Mr. Burton was formerly the chief engineer and works manager of the Lorain Steel Company.

V V

T. A. Martin, formerly foundry superintendent with the George H. Smith Steel Castings Company, Milwaukee, is at present directing a new steel foundry for the Erie Forge Company.

V V

E. L. Ives has resigned his position with the Steel & Tube Co. of America, to become associated with Brassert,

Hardy & Tripp, Chicago, owners of the Miami Metals Co., and other iron and steel interests. He will assist Mr. Brassert in reporting and consulting work in the iron and steel industry. He is a graduate of Yale and started his career with the Newport News Shipbuilding & Drydock Co. In 1906 he entered the employ of the Illinois Steel Company, at South Chicago, and was assistant superintendent of blast furnaces until 1912 when he was made manager of the Iroquois Iron Company's plants at South Chicago.

V V

E. A. Barrows, Jr., was re-elected president and general manager of the Thomas Iron Company, Hokendauqua, Pa., at the annual meeting of the company last week. Other officers elected at this meeting were: Fred R. Drake, Easton, vice-president; Oliver T. Case, Allentown, secretary-treasurer; Julius E. Rothaus, Catasauqua, assistant to the president and auditor.

V V

Marcus Grossman has been appointed chief metallurgist of the Electric Alloys Steel Company, of Youngstown, O. Mr. Grossman is a graduate of the Massachusetts Institute of Technology and is at present connected with the Westinghouse Electric and Manufacturing Company.

Corresponding Representatives Wanted

THE BLAST FURNACE AND STEEL PLANT desires to secure representatives in every steel center in this country and foreign countries, who will report personal items, plant news, news of new constructions, etc.

If you care to act as a representative fill in the blank below and send it to the editor of THE BLAST FURNACE AND STEEL PLANT, Box, 65, Pittsburgh Pa. The editor will then communicate with you concerning your appointment and remuneration.

Name Address

Company connected with Position



E. D. Baker is now general manager of the Merchants Metals Corporation, New York. Mr. Baker was for a number of years purchasing agent of the American Steel Export Company, New York. He is succeeded by J. Edmund Good.

✓ ✓

Robert J. Mullally is now in charge of the 84 and 132-inch plate mills of the Brier Hill Steel Company, Youngstown, O. Mr. Mullally was formerly superintendent of the bar mills of the McDonald, Ohio, plant of the Carnegie Steel Company. Mr. Mullally succeeds N. H. Eshelman, resigned.

✓ ✓

Charles E. Dinkey, who has been connected with the Carnegie Steel Company since 1880, and who has been general superintendent of the steel works and blast furnaces of the Edgar Thomson Works of the Carnegie Steel Company since 1903, has resigned, effective April 1. Mr. Dinkey was connected with the Mackintosh Hemphill & Co., for a brief period.

✓ ✓

Harry C. Davis has resigned as superintendent of the Thomas and Empire works of the Brier Hill Steel Company, Niles, O. Harry Holloway will succeed Mr. Davis as superintendent of the Empire and Thomas hot mills.

✓ ✓

Trusten P. Draper, general superintendent, Sharon Steel Hoop Company; J. D. Lyons, of the A. M. Byers Company, and A. F. Braun, of the Farmers Deposit National Bank, Pittsburgh, have been added to the board of directors of the Sharon Steel Hoop Company, Sharon, Pa.

✓ ✓

Lawrence J. O'Laughlin, of Perin & Marshall, Rector street, New York, has recently sailed from San Francisco for China, concerning the inspection of steel mills being erected by Perin & Marshall in China.

✓ ✓

John McKay, who has been superintendent of the Greenville, Pa., plant of the Carnegie Steel Company for the last 12 years, has been made assistant superintendent of the bar mills of the McDonald plant of the Carnegie Steel Company, McDonald, O.

✓ ✓

At the annual meeting of the Elyria Iron & Steel Co., Cleveland, the following directors were elected: Hugh B. Wick, Myron A. Wick, George F. White, William T. Bentz, Walter Ferrier, G. R. Guyon, George C. W. Klippel. The directors subsequently organized as follows: President,

Hugh B. Wick; vice-president, Myron A. Wick; secretary-treasurer, George F. White; assistant treasurer, George C. W. Klippel.

✓ ✓

Clarence A. Miller has been appointed superintendent of the bar mills of the McDonald works of the Carnegie Steel Company succeeding Robert J. Mullally. Mr. Miller was promoted from the position of assistant superintendent.

✓ ✓

D. J. Flynn, open-hearth superintendent of the Tacony Steel Company, Tacony, Pa., is now connected with the New Castle plant of the Penn Seaboard Steel Corporation, with which the Tacony Steel Company recently merged.

✓ ✓

Joseph P. Nelson, formerly foreman at the Trumbull Steel Company, Warren, O., is now superintendent of rolling mills of the Weirton Iron & Steel Co., Weirton, W. Va.

✓ ✓

At the recent annual meeting of the Sloss-Sheffield Steel & Iron Co., the following new directors were appointed: Hugh Morrow in place of L. Sevier, James N. Jarvie in place of M. C. Branch, and J. P. Davidson to succeed the late J. N. Wallace.

✓ ✓

Joseph Boyer has resigned as a member of the board of directors of the Truscon Steel Company, Youngstown, O., and is succeeded by Thomas H. Kane, vice-president and works manager of the company.

✓ ✓

John A. Guyer, formerly connected with the Cambria Steel Company and the Donner Steel Company, has recently been appointed Cleveland district sales manager for the L. D. Rockwell Co., Detroit.

✓ ✓

H. A. Rapelye has been appointed sales representative for the western portions of Pennsylvania, New York, Maryland, Eastern Ohio and West Virginia for the Electro Dynamic Company, Bayonne, N. J., manufacturers of alternating and direct current motors and direct current generators.

✓ ✓

R. E. Brakeman is chief engineer of the Otis Steel Company and not general manager, as incorrectly stated in the March issue. Mr. Brakeman was formerly chief engineer of the Fairfield works of the Tennessee Coal, Iron and R. R. Company.

INDUSTRIAL RELATIONS

SAFETY METHODS OF THE UNITED STATES STEEL CORPORATION.

Welfare in general is a feature in modern industrial activities which has for its object certain benefits, and the creation of plant and home environments which will contribute to the happiness, health, and comfort of the workers and their families. The attitude of the worker at his daily task is as much a psychological condition as it is a matter of physical strength and skill and will be determined to a large degree by the influences with which he is surrounded both in the plant and in the home. Welfare work should be of a character that influences the life of a worker in such a manner as to establish a co-operative interest in his work, foster within him a spirit of contentment in his home and lead him so to employ his leisure time as not to lower his efficiency as a worker and destroy his domestic happiness, or endanger his standing as a citizen in the community.

So progressive has been the movement, with the realization of its importance, that the majority of our industrial concerns have taken definite steps to organize the work thoroughly. I will endeavor to outline in a general way the activities of the United States Steel Corporation and its subsidiaries in connection with the welfare of their employees. This is as set forth and illustrated in Bulletin 7 of the Bureau of Safety, Sanitation and Welfare of the United States Steel Corporation.

Organization.

In order to systematize and standardize the work that was being done by the subsidiary companies, the United States Steel Corporation, in 1906, appointed committees to study these matters. A safety committee was appointed, consisting of representatives from the larger subsidiary companies which had already given some study to the subject of accident prevention. This committee has been continued and now meets four times each year, conducts inspections by sending men from one company to another, studies serious accidents and recommends measures to prevent the recurrence of such accidents in any of the plants, passes upon safety devices and makes recommendations as to their use.

The good which resulted from the work of this committee led to the appointment of other safety committees, including the central committee of safety for each subsidiary company, composed of representatives from the different plants of the Corporation. The duties of this committee are similar to those of the safety committee of the Corporation, but with reference to its particular company only. This plan is followed at the plants of the various companies, by the appointment of plant committees composed of important officials of the plant. Their duties are similar to those of the central safety committee but with reference to their respective plants only. At the plants, there have also been appointed safety engineers and the departmental and special committees made up of foremen and department heads as outlined in previous paragraphs, who investigate particular problems relating to safety in the plant and the various departments. The results of the work on accident prevention have been very gratifying. The serious and fatal accidents are about one-half what they were in 1906. It is estimated that approximately 23,000 men have been saved from serious and fatal injury, while the reduction of other injuries of a less serious nature has been very pronounced—in some instances reaching as high as 97 per cent.

First Aid and Rescue.

Recognizing the fact that with the utmost care and the protection afforded by the most approved safety devices and

From paper read before Engineers' Society of Western Pennsylvania, by H. A. Schultz.

apparatus, accidents will occasionally happen, the subsidiary companies have made provision for prompt attention to injured men and skillful care of them.

All the mining companies of the Corporation have first aid and rescue crews composed of employees who are especially trained for the work. This service is purely voluntary on the part of the employees, but before any man is allowed to enter the work, he must have a doctor's certificate showing that he is physically fit for the training and labor incident to it. The system varies slightly in each company, but the general plan is as follows: Four to six men are assigned to each crew. They meet periodically and are trained by the company doctor. The course consists of lectures, demonstrations, and drills. Twelve lessons are usually required to complete the course, and each man is given a certificate after he has qualified. The training of the men for the work goes on continually and many new crews are added each year. A number of crews are assigned to each mine.

At many of the manufacturing plants of the subsidiary companies of the Corporation, men are trained in first aid work. The training is similar to that given in the mining companies. The primary object of first aid is to furnish an aseptic or clean dressing that will prevent infection in the wound.

As a necessary adjunct to first aid and rescue work in both mines and mills, emergency hospitals, completely equipped have been provided. All cases of injury, no matter how trivial, are sent to the emergency hospitals or stations, where treatment is given by competent surgeons or trained nurses. Whenever the accident is of a serious nature, the injured man is taken to the emergency station, where first aid treatment is administered, and he is then transferred to the nearest hospital.

Relief.

Recognizing the fact that the burden of caring for the injured should be borne by the industry, the United States Steel Corporation established a voluntary accident relief plan, which was put into force before any such system had become law in the United States. This plan is purely voluntary and was put into operation by the Corporation in May 1910, and is for the benefit of all employees injured, and the families of employees killed, in the service of the subsidiary companies. The funds required to carry out the plan are provided by the companies, with no contribution whatever from the employees. Relief is paid, regardless of legal liability and without legal proceedings; even application for relief is not required. This plan of relief is still in effect in those states where workmen's compensation laws have not been enacted.

Sanitation.

The work in sanitation has been organized in a manner almost identical with the safety organization, except that the sanitation committee is chosen from the presidents of the subsidiary companies with an officer of the United States Steel Corporation as one of its members. This committee administers the work through a sub-committee composed largely of technical representatives from each of the subsidiary companies.

In sanitation, many improvements have been made in the proper investigation and observation of water-supply and distribution to employees. All sources of drinking water are analyzed periodically and great care is taken to prevent possible pollution by surface water or otherwise. The most modern sanitary methods are employed in the cooling and distributing of the water, including the installation of sanitary drinking fountains, and the common drinking cup has been practically eliminated.

Some Pointers on By-Product Coke Oven Operations

PLANT CAPACITY FOR THE MANUFACTURE OF BY-PRODUCT COKE.

The capacity of a coke oven naturally depends upon the number of hours adopted as standard coking time. The maximum capacity of the by-product plants of the country, defined as "the maximum quantity of coke of the grade desired by the operator which can be produced when all conditions are favorable, with all ovens active," has been as follows:

Table 1.—Maximum Capacity of By-Product Coke Ovens in the United States, 1918-1920, in Net Tons per Annum.

January 1, 1918.....	27,000,000
January 1, 1919.....	33,700,000
January 1, 1920.....	39,500,000

In the year 1918 there was thus an increase in the annual capacity of coke ovens amounting to 6,700,000 tons, or 25 per cent. The increase during the year 1919 was somewhat smaller, 5,800,000 tons, or 17.2 per cent.

The annual capacity of the plants completed and in operation at the beginning of 1920, including ovens temporarily idle, was 39,500,000 net tons. This figure represents the output at full capacity—operation of 100 per cent. In actual practice an average operation above 90 per cent can not be assumed for the country as a whole. Weekly reports received from the by-product plants during the war show that from December 28, 1917, to February 1, 1919, the highest percentage attained for the entire country was 92.2, the output reached in the week ended September 28, 1918. The average for the year 1918, when every effort was being made to speed up the recovery of by-products, was 86.9 per cent of maximum capacity. The average for 1919 appears to have been about 70 per cent.

In estimating the coke or the by-products recoverable from the country's existing by-product ovens the assumed percentage of operation should therefore not exceed 90 per cent. Indeed, the safer figure of 85 per cent would appear better justified by experience. The present capacity of the by-product ovens of the country in net tons per annum would therefore be that shown in table 2, the yield of coke from coal being taken as 71.2 per cent, the average for 1917-18.

Table 2.—Capacity of By-Product Coke Ovens in 1920.

	Coke	Coal for charge
Assuming 90 per cent operation.....	35,500,000	49,800,000
Assuming 85 per cent operation.....	33,600,000	47,100,000

The completion of the plants now under construction may raise the capacity to a maximum of approximately 43,300,000 tons, or 36,800,000 tons under an operation of 85 per cent. In connection with the supposition that a limit to the production of by-product coke may be reached, it may be noted that this quantity is 65.2 per cent of the coke produced in 1918, the largest quantity ever used by the country in one year. It is 69 per cent of the coke required for producing 49,666,000 gross tons of pig iron, the annual capacity of the coke-burning blast furnaces completed or building on January 1, 1919, according to the annual statistical report of the American Iron and Steel Institute, the coke consumption being taken at 2,375 pounds per gross ton of iron. It is 61.7 per cent of the country's total requirements for coke in the war year, 1918, as estimated by the United States Fuel Administration, less sales of gas-house coke, amounting to 1,814,000 tons.

Recovery of By-Products.

Final statistics showing the quantity and value of by-products recovered in 1919 are not yet available, but an idea of the quantity may be obtained by multiplying the number of tons charged into the ovens in 1919 by the average quantity of by-products recovered in 1918 per ton.

Table 3.—Average Recovery Per Net Ton of Coal Charged Into By-Product Ovens in 1918.

NH ₃ (all forms) expressed in terms of equivalent ammonium sulphate, pounds	18.9
Tar, gallons	7.1
Crude light oil, gallons	2.4
Gas, M cubic feet.....	10.4

The figures, if multiplied by the 35,353,000 net tons of coal charged in 1919, as estimated from known coke production on yield of 71.2 per cent, the average for 1917-1918, would give 668,200,000 pounds of ammonium sulphate or its equivalent, 251,000,000 gallons of tar, 84,800,000 gallons of crude light oil, and 367,700,000 cubic feet of gas.

For purposes of comparison the actual production of by-products in 1918 is re-printed below:

Table 4.—By-Products Obtained From Coke-Oven Operations in 1918.

Products	Production	Sales	Value of Sales
Tar, gallons	263,299,470	200,233,002	\$6,364,972
Ammonia:			
Sulphate, pounds.....	436,388,134	423,515,836	19,061,777
Liquor, gallons			
Anhydrous or free ammonia*, pounds.....	65,230,159	61,442,933	7,381,174
Gas:			
Illum'g. and household purposes, 1,000 cu. ft. }	385,035,154	33,437,991	7,130,113
Indus. Pur., 1,000 cu. ft. }		124,920,488	6,569,402
Benzol products:			
Crude light oil, gals..	87,222,450	3,764,272	963,042
Secondary light oil, gals.	339,644	121,191	15,472
Benzol, gals.	44,804,900	43,441,980	11,966,367
Toluol, gals.	8,861,948	8,541,366	12,249,702
Solvent naphtha, gals.	3,540,162	3,123,815	439,983
Other oils gals.	636,707	571,752	53,880
Crude naphthalene, lbs	10,614,799	10,403,758	287,648
Refined naphthalene lbs.	5,472,699	5,486,639	362,648
Other products†			1,756,345
Total			\$74,602,458‡

*Includes liquor and sulphate sold by pound of NH₃.

†Includes sodium ferro cyanide, pyridine oil, nut coke, drip oil, spent oxide, residue, coal-tar paint and wash oil.

‡Does not include value of 1,999,370 net tons of coke breeze.

If the figures showing the recovery of by-products per ton are multiplied by the number of tons given above as the annual coke capacity of the ovens now built and building in the United States, namely, 36,800,000 tons—a moderate estimate assuming 85 per cent operation—the annual capacity for the recovery of by-products by the end of 1920 will become 977,100,000 pounds of ammonium sulphate, or its equivalent, 367,000,000 gallons of tar, 124,000,000 gallons of crude light oil, and 537,300,000,000 cubic feet of gas.

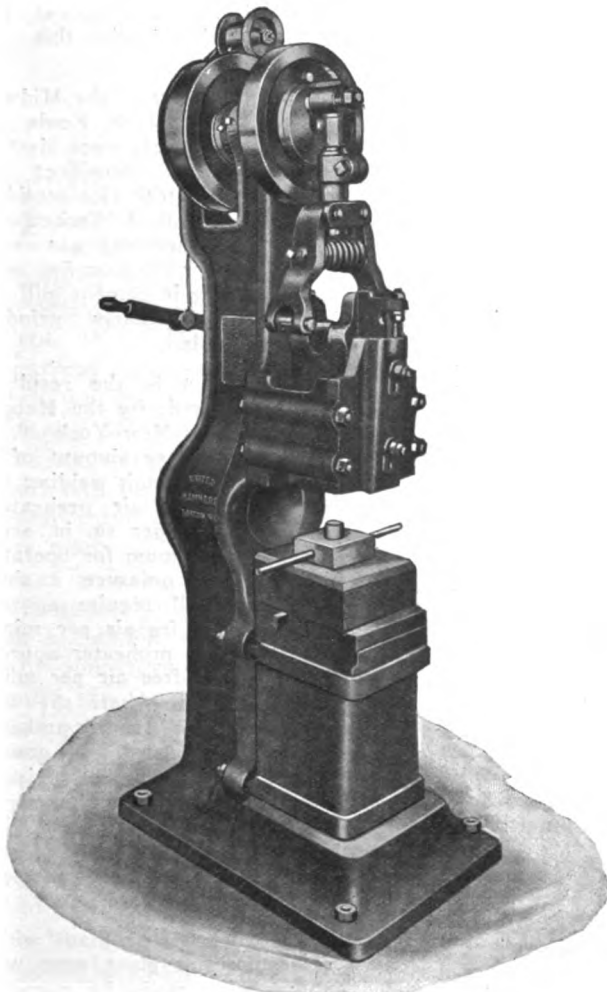
(Geological Survey Report.)

WITH THE EQUIPMENT MANUFACTURERS

SPECIAL PULVERIZING MACHINE.

The accompanying cut illustrating the Fairbanks power hammer equipped with pulverizer, designed for use in chemical laboratories for pulverizing pig iron samples for analytic purposes. This is a time and labor saving device, which will reduce $\frac{1}{2}$ -inch to $\frac{3}{4}$ -inch cubes in two to three minutes so that particles are fine enough to pass through an 80-mesh sieve.

In one plant where this machine has been installed it took three men using 26-pound sledges to reduce $\frac{1}{2}$ -inch cubes by ordinary hand methods. After installing one of these machines they were able to dispense with two men, as well



Special hammer for pulverizing.

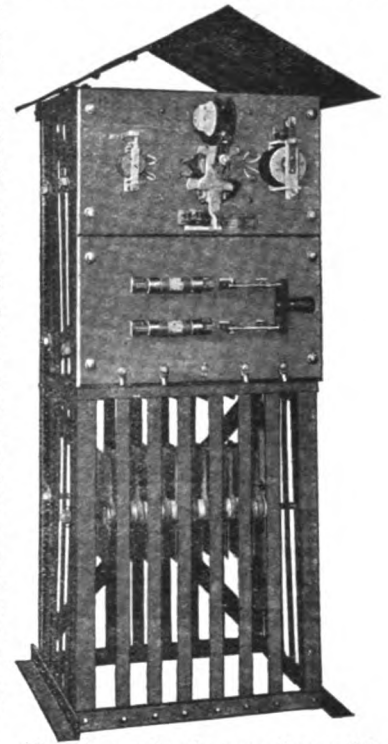
as cut the operation down from 12 to 2 minutes, showing considerable saving in labor and time consumed in the process, as well as a more uniform result.

This machine is built either for belt or motor drive. It is built in one size only, having a 100-pound ram and a 2-inch mortar and pestle.

The hammer is operated by a foot treadle at the base of the machine, or by a special starting device, as shown in illustration. It is simple in operation, under the control of the operator at all times and is capable of striking an approximate blow of 600 pounds when running at 300 revolutions per minute.

CONSTANT POTENTIAL CHARGING EQUIPMENT.

For the automatic charging of mine locomotives having Edison storage batteries the new C-H charging Panel shown in the illustration has been designed by the Cutler-Hammer Manufacturing Company, of Milwaukee and New York. It may be connected to a 250 to 275 volt direct current circuit since this is the service available at most mines. The equipment consists of a slate panel supported by a floor type mounting frame having the charging resistance self-contained. A sheet metal roof protects the charging resistance and the magnetic switches on the panel from the mine drippings. The switch equipment on the front of the panel consists of a main line knife switch with renewable fuses, magnetic main line contactor, voltage relay and shunt trip relay.



Charging mine locomotives with this new automatic charging panel requires no attention.

The main line contactor, which connects and disconnects the battery from the line, is controlled through the voltage relay and the shunt trip relay. The former prevents it from closing unless the line voltage is of sufficient value for charging, and causes it to open if the power fails or the line voltage drops below a predetermined value, thereby guarding against the batteries discharging back into the line. On restoration of the power after a power failure the main line contactor automatically recloses, and the charge is continued. The shunt trip relay is connected to the ampere-hour meter on the locomotive and when the battery is fully charged the ampere-hour meter will energize the relay which in turn causes the main line contactor to open and disconnect the battery from the line. This relay also opens the contactor should the line voltage become too high. Thus the voltage and shunt trip relays permit charging only when normal conditions prevail on the line.

STATEMENT OF OWNERSHIP, MANAGEMENT, ETC., OF

The Blast Furnace and Steel Plant

[Required by the Act of Congress of August 24, 1912]

Name of Publication: **The Blast Furnace and Steel Plant**, published monthly at Pittsburgh, Pa. [Report for April, 1920.]

Publisher—The National Iron and Steel Publishing Company, 108 Smithfield street, Pittsburgh, Pa.

Editor—Alfred M. Staehle, 108 Smithfield street, Pittsburgh, Pa.

Managing Editor—Herbert A. Andresen, 108 Smithfield street, Pittsburgh, Pa.

Business Manager—Fred C. Andresen, 108 Smithfield street, Pittsburgh, Pa.

(Names and addresses of stockholders holding 1 per cent or more of total amount of stock:

Herbert A. Andresen, 108 Smithfield street, Pittsburgh, Pa.

Fred C. Andresen, 108 Smithfield street, Pittsburgh, Pa.

Known bondholders, mortgagees, and other security holders, holding 1 per cent or more of total amount of bonds, mortgages, or other securities: None.

FRED C. ANDRESEN, Business Manager.

Sworn to and subscribed before me this 23rd day of March, 1920.

JOHN N. ENGLISH, Notary Public.
(My commission expires March 9, 1923.)

TRADE NOTES

Mr. D. T. Newman, formerly connected with the Philadelphia sales office of the Yarnall-Waring Co., has been placed in charge of their Atlanta office, recently opened in the Candler Annex, Atlanta, Ga.

Charles F. Overly has recently been appointed general manager of sales, of the Structural Tool Company, of Cleveland, Ohio. For years Mr. Overly was connected with the manufacture of pneumatic tools, after which he formed the Overly Industrial Tool Company, becoming president of same. Upon the formation of the Structural Tool Company, Mr. Overly was induced to combine forces with the new corporation. The company is located in its new plant on West 106th street, Cleveland. They manufacture rivet sets, chisel blanks, punches, dies and pneumatic tool parts.

The Brown Instrument Company, Philadelphia, Pa., is erecting two new buildings, one for the manufacture of recording thermometers, the second a research department, at a cost of \$100,000. These facilities will enable this company to materially increase the output of Brown pyrometers and recording thermometers.

The combination recently announced of the organizations of Westinghouse, Church, Kerr & Co., Inc., Engineers and Constructors, New York, and Dwight P. Robinson & Co., Inc., Constructing and Consulting Engineers, of New York, is of general interest. The new company will be called Dwight P. Robinson & Co., Inc., and will occupy executive offices at 61 Broadway and engineering and designing offices in the Grand Central Palace, 125 East 46th street, New York. Mr. Dwight P. Robinson, president of the new company, was for many years president of the Stone & Webster Engineering Corporation, and formed his own company in 1918. He has had an unusually valuable experience in the design and construction of industrial plants, large central power stations and hydro-electric plants, and his company, the principals of which left Stone & Webster with him, has specialized in work of this nature. At the time of the merger, the Robinson company had large power plants under construction for the Duquesne Light Company, at Pittsburgh, the Penn Public Service Company, at Johnstown, Pa., and others.

Westinghouse, Church, Kerr & Co., Inc., established 36 years ago, has specialized in the design and construction of industrial plants of all kinds, railroad shops and terminals, and industrial power plants.

The Metal & Thermit Corporation, New York City, N. Y., in order to more adequately take care of its rapidly increasing business in the New England states and in Canada, has appointed Mr. James G. McCarty manager of its Can-

adian branch, with headquarters in Toronto, and has transferred Mr. Robert L. Browne from its New York office to Boston, where he will have charge of all sales in the New England states. Mr. McCarty was graduated from Stevens Institute of Technology in 1906 and became affiliated with the Metal & Thermit Corporation in 1909. He has had a wide and varied experience with all phases of the Thermit Process and has represented the company in many sections of the United States and Canada.

The Mesta Machine Company has recently received the following orders for building pickling machines: Two for the Republic Iron and Steel Company for pickling sheets; two for Otis Steel Company for pickling sheets; one for Cadillac Motor Company for pickling automobile forgings; one for Baldwin Canadian Steel Company for pickling sheets, and one for Morris & Bailey for pickling sheets. This makes the third pickling machine for Morris & Bailey. Recently the following shipments of pickling machines have been made: One to American Rolling Mill Company for pickling sheets; one to Newton Steel Company for pickling sheets; one to Youngstown Pressed Steel for pickling sheets; one to Bethlehem Steel Company for pickling sheets; one to Willys Morrow Company for pickling automobile forgings, and four to Eastern Rolling Mill Company for rolling sheets.

Ray T. Middleton has resigned as general sales manager of the Standard Steel Castings Company, of Cleveland, to become vice-president and director of sales and advertising for Kelly Metals Company, of Chicago, Detroit and Los Angeles. Mr. Middleton's headquarters will be Chicago, where the Kelly Metals Company, will, at an early date, establish its principal production plant. The company will continue its present plants in Detroit and Los Angeles and later establish a third branch plant, at a point to be selected in the east.

The American Steam Conveyor Corporation announces the appointment of the Kon-Wald Engineering Company, Mutual Life Building, Buffalo, New York, as their representatives in Buffalo and Western New York. Mr. F. A. Konzelman, manager of this company, is well known in the engineering circles in that vicinity. The Brooks-Fisher Company, Candler Building, Atlanta, Georgia, has been appointed southeastern representatives of the American Steam Conveyor Corporation. The Brooks-Fisher Company is a comparatively new concern, having been organized early last summer to carry on a business of manufacturers, agents and contractors. Mr. J. M. Fisher was for 15 years in the erection department of the Babcock & Wilcox Co., the last six of which he was district superintendent for the Atlanta territory. E. A. Brooks, the other member of the firm, was, up to the time of the organization of the concern, assistant sales manager for the Atlanta office of the Babcock & Wilcox Co. He is a

graduate of Georgia Technical College, and an associate member of the American Society of Mechanical Engineers, and has had considerable experience both in the operating and the sales end of the boiler business.

Freyn, Brassert & Co., engineers, Chicago, have recently received order from the Steel & Tube Co., of America, Mark Plant, for Birkholz-Terbeck Burners, for installation on 3600 boiler hp four pass Stirling Boilers. This installation of boilers is in addition to 3600 boiler hp now in operation on which Birkholz-Terbeck Burners are installed. These boilers are operating at 180 per cent overload on straight blast furnace gas firing. This is believed to be most exceptional performance. Freyn, Brassert & Co., engineers, Chicago, have taken an order to equip four stoves of the LaBelle Iron Works, Steubenville, Ohio, with Mathesius valves. All eight stoves at this plant are now equipped with this type of valve.

At the annual meeting of the Midwest Forge & Steel Co., East St. Louis, Ill., the following new officers were elected: J. W. Eschenbrenner, president and treasurer; C. T. Coates, vice-president and general manager; E. A. Eschenbrenner, secretary. The business was established in 1885, and for the past five years has been specializing in cement mill and mine forgings, particularly grinding plates and steel balls.

The following data is the result of some recent tests made by the Metal & Thermit Corporation, New York, N. Y., to determine the proper amount of air required for special thermit welding gasoline and compressed air preheaters:

Twenty-five pounds per sq. in. seems to be a practical minimum for operating preheaters. At this pressure, a single burner preheater will require approximately 25 cu. ft. of free air per minute and a double burner preheater approximately 25 cu. ft. of free air per minute. For very large welds, where the walls of the molds are thick and the preheater gates longer than usual, a pressure of 40 lbs. per sq. in. would be advisable, which would require approximately 35 cu. ft. of free air per minute for a single burner preheater and 70 cu. ft. of free air per minute for a double burner preheater.

In the case of a large plant with a central air compressor plant, upon which demands are being made by many departments, the pressure quoted above should be maintained at the outlet to which the preheaters are attached.

Ellenwood & Doyle, of 29 Great Jones street, New York City, who have just completed their first year as distributors of tin plate, black and galvanized sheets, copper, brass, zinc, etc., in order to provide additional capital for their rapidly expanding business, have decided to incorporate under the laws of New York State for \$150,000 8 per cent preferred stock and 1,000 shares of common stock of no par value.

The Blast Furnace *and* Steel Plant

Pittsburgh, April, 1920.



"NOHEET"

Which Bearing Metal Would You Choose?

On the left is a series of microphotographs showing in minute detail the physical properties and characteristics of several bearing compositions. Out of the four specimens only one shows a uniformity of texture, free from sharp brittle materials such as copper, spelter and antimony. Why tolerate the troublesome shaft scoring that arises from imperfect bearing material when the elimination of these costly delays can be effected by specifying

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